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DEVOTED TO

SCIENCE AND THE MECHANIC ARTS.

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Mechanical and Engineering Section.

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THE AUTOMATIC GUN AND ITS MILITARY ASPECTS.

BY CECIL HAMELIN TAYLOR.

An automatic gun is one in which all operations to reload and again fire the arm, are executed by energy derived from the discharge of the preceding cartridge.

A gun operated by the rotation of a spindle, manually, by clockwork or by a motor, is not automatic, since the power for operation is originally derived from an external source.

A machine gun is one adapted to be mounted on a support, and in which the handling of the ammunition from a reservoir is done mechanically, irrespective of the source of power. If this power be obtained from the energy of explosion of a preceding cartridge, the arm is an "Automatic Machine Gun," in contradistinction to the "Crank

Machine Gun" operated by turning a crank by hand, and "Motor Machine Gun" operated by an electric or other motor.

The motor gun is confined to naval and militia work and is not in general use. It is nothing more than a crank gun with a motor attached to the driving shaft.

The crank gun has rendered excellent service on many occasions. The Hotchkiss revolving cannon and the Gatling, Gardner and Nordenfelt machine guns are all of this type. They are multi-barrelled guns in which each barrel is fired singly in succession. The rate of fire with a ten-barrelled Gatling gun has attained about twenty shots per second. The cartridges are fed from drums containing several hundred each.

Automatic machine guns are usually single-barrelled, and are fed with a belt holding the cartridges, the mechanism extracting the cartridges from the belt, inserting them into the gun, firing and ejecting the empty cartridge case entirely by the force of explosion generated in the gun itself. These guns have attained a rate of fire of over ten shots per second.

In all varieties of machine guns the size of ammunition may vary from rifle-calibre to full-calibre, throwing a projectile weighing over a pound. Naturally the larger the cartridge used, the larger, heavier and slower is the gun.

Some confusion has arisen in the use of the term "semi-automatic" applied to ordnance. It could be properly used to denote a gun in which any number of its necessary functions are performed automatically, while the remainder are executed by external agents. The term has been applied in two different technical senses to cannon and to rifle-calibre arms. The "semi-automatic" *cannon* is one in which the opening and ejecting (and usually the closing and locking) are done automatically, the charge being inserted by hand. In the "semi-automatic" *small-arm*, all functions except releasing the trigger are automatically performed.

Though it has been but twelve years since the first of the modern small-bore hand repeating rifles was definitely adopted for the armament of the German Army, yet already

the opinion is widely held in military circles that the hand-repeater must shortly be superseded by the automatic small-arm.

In the Reichstag on December 12th of last year (1900), General Von Gossler, referring to the reports that a division of the German Army was to be re-armed, admitted that in order to keep abreast of modern requirements the War office was negotiating with a Swedish inventor for the model of an automatic breech-loader. Thus, as is usual, in military innovations, Germany takes the lead. Already the cavalry of Germany, Italy and Switzerland are arming with automatic pistol-carbines, and experiments with automatic guns are being constantly conducted in France and generally throughout Europe.

The automatic machine gun has been adopted by both services of every great power, and has already done splendid work in service. In our army the Colt gun has been provisionally adopted. The navy department is at present manufacturing automatic full-calibre guns under Maxim's patents, and has, I believe, also a number of Colt guns in service. All existing examples of automatic guns are, however, more or less imperfect, and it is safe to say that no one gun of this nature has demonstrated any marked degree of efficiency over other good examples of its class.

I shall endeavor in this paper to examine into the general theory and practice of automatic gun construction for the purpose of indicating some of the many causes of failure in most of these weapons in the past, as well as the probable lines of the most satisfactory future development.

There are certain broad desiderata for all types and classes of automatic fire-arms: Positiveness, strength, simplicity, compactness and minimum recoil.

The first is positiveness. This is difficult to define correctly. For a mechanism to be positive, as few as possible parts working independently from the main mechanism, and a minimum number of springs should be used. The cartridge from its entrance into the gun until the ejection of the empty case should be held securely at all times. The fundamental mechanical motions of all parts of the mechan-

ism should be such that the maximum frictional coefficients remain low.

This question of positiveness determines to a great extent the limiting amount of abuse through which the arm will remain operative. Under service conditions guns are subjected to severer usage than any other class of similar mechanism. Powder residue and unburned grains of smokeless powder, sand and dust, mud, rust and frozen oil all do their share in clogging the action.

In view of these facts the main problem becomes that of utilizing a fraction of the energy of explosion through as frictionless as possible a mechanism, with a minimum total working surface, in such a way that at any instant a maximum of energy shall be available for overcoming resistances to the cycle of operation. Not only should there be a minimum total working surface, but motion on these surfaces should be as short as possible, and the surfaces should be unbroken, so that foreign matter can not interpose itself in such a way as to place the mechanism in a shearing or crushing position. The speeding of the main pieces, especially of the breech-block, should be such as to give increasing force with lessening velocity in the first part of the opening motion and in the last period of closing, in order to more surely overcome resistance to extraction of the fired case or to the insertion of a live cartridge. The question of compactness and lightness is the last but not the least consideration, and further greatly complicates an already involved problem.

All existing examples of automatic guns designed until recently, have points in common; the block in its cycle is guided by grooves or slots, and a form of firing pin, either primary or intermediate, is used. I estimate from my own experiments and from the detailed official records of trials conducted to simulate service conditions, that fully 90 per cent. of failures to operate under various forms of abuse are directly due to this construction.

The program of trials for military fire-arms generally consists in tests for safety, ease of manipulation, rapidity of fire, ballistics, and ability to resist the action of defective ammunition, rust and dust.

It will be seen that an arm must be satisfactory in *all* particulars, and that failure in any one will condemn it. The question of ballistics alone is independent, generally speaking, from that of the mechanism.

Every fire-arm which can lay any claim to efficiency must be safe, easy of manipulation and compact. The ability, then, to resist defective ammunition, rust and dirt, becomes the subject for investigation.

In the United States trials for selecting a hand magazine arm to supersede the Springfield single-shot rifle, of the fifty-three arms examined, only two passed through the entire trial without breaking or clogging to such an extent that the mechanism worked with difficulty. Twenty-three guns, including models of the best European military rifles now in use, were more or less incapacitated, owing either to rusting or dusting, while four others, after passing through the dust test successfully, were disabled before arriving at the rust test. Of the twenty-three more or less unsuccessful guns, three—one of which was only a single-loader—failed only through rust; seventeen only through dust; while three failed from both causes. The firing-pin caused five failures; the magazine caused four, and the sticking of breech block in its slide occurred in eighteen cases. It is probable that the firing-pin would have given much more trouble than is indicated from these figures, were it not for the fact that in those cases in which the block was permanently jammed the condition of firing-pin was not examined, the failure of the gun being attributed solely to the sticking of the block.

Dangerously defective ammunition is of two kinds: In one the cartridge case becomes ruptured on firing, allowing gas to escape into the mechanism, straining parts and fouling the action. In the other the charges may be either greater or less than normal, giving greater or less breech-pressure. With excessive charges the fermeture, or locking device, is unduly strained, and in automatic guns with reduced charges, the power for operating is lessened.

In the above-mentioned tests of hand repeaters, twenty-seven guns were tested with these forms of defective ammu-

nition prepared for the purpose, the excessive pressure being limited to about 50,000 pounds per square inch. Of these twenty-seven, sixteen passed through the ordeal satisfactorily, and eleven were not repaired to undergo this test. In eight tests the weakened cases caused broken extractors, due to their being unsupported when in the locked position. In each of the twenty-seven guns tested properly placed vents to lead the escaping gases from the cartridge head to the atmosphere would have done much to prevent damage. Supported, strongly made extractors, in addition to the vents, would have entirely prevented it. Firing-pins of all kinds should, where possible, be replaced by some form of swinging hammer, as the effect of rust and dirt can be made much less with this construction than is possible where a firing-pin is employed. When we consider that with modern methods of ammunition manufacture there is only one defective round in about 10,000 to 20,000, we see that resistance to defective ammunition is probably the least of many desiderata for small-arms.

I now come to the real problem of the automatic gun; namely, that of reducing friction and of being able to use the maximum of energy at any instant for overcoming accidental resistances.

Formulae for friction used in machine design cannot be used in gun design, as they are based on a more or less perfect lubrication of working surfaces. Not only does a firearm have to work dry of oil, but, as above mentioned, its hould be usefully operative when cemented with rust and dirt. Under fixed conditions this cementing will then be in proportion to the amount of working surface, the distance travelled on the surface, the tightness of the joints, and the finish and quality of the metal employed.

The first factor is that of the amount of working surface, and the distance travelled by the parts while in contact. There are these four methods of communicating and guiding mechanical motions: (1) by rolling contact, (2) by sliding contact, (3) by wrapping connections, and (4) by link-work. True rolling contact for guiding is practically frictionless. As a power medium it is uncertain, since the

relation of parts in reciprocating movements depends on frictional adhesion, so that the relation of parts may become altered. It also has the disadvantage of becoming a crushing device in the case of dusting. This means may then be considered generally inapplicable to ordnance, and more particularly to small-arm construction. Motion by wrapping connections is really but a form of motion by rolling contact, and should be classed as such. It is open to the same objections and may also be discarded. Motion by sliding contact is obtained by gearing, cams, and pin-and-slot movements. In these ways as a power medium sliding contact is much used, but its use as a guide in the form of a bolt and sleeve construction is universal.

Gears, cams, and pin-and-slot movements may be used in a manner to give fair results. Gears can with difficulty be made to run smoothly without "backlash;" they exert a crushing action on any dirt on their surfaces, and are liable to breakage, owing to the sudden blows to which they are subjected in automatic guns, unless made of a size incompatible with the compactness desired in small-arm construction. For quick-firing ordnance of the semi-automatic type, gearing has been used successfully, as compactness is here not a vital requisite. In cam, and pin-and-slot motions, unless rolls be employed, there is much motion and large working surface. Where rolls are employed, simplicity and strength are both sacrificed to a certain extent.

In guiding the bolt by a sleeve we see the result of the neglect on the part of designers to consider the peculiar features of automatic gun construction. The sleeve is mechanically the most perfect way of guiding a reciprocating piston. Strength and a true straight line motion are obtained, and the gun under *steam engine* conditions is ideal, but under military *service* conditions a mallet and drifts are sometimes required to put the piece in operative condition, and by such means parts are frequently injured. Link-work may be used as a powder medium and as a guide, and offers decided advantages over other means. If a breech block can be swung on link-work entirely without other contact than at

the link pins, the total working surface will be reduced to a minimum, as well as the amount of travel on such surface. Further, a pin can be commercially fitted to a bearing with such precision that once oiled or waxed, the entrance of water and dirt will be prevented, without making the mechanism unduly stiff. Direct obstruction to the bearing surfaces cannot occur, and there can be no crushing action except by the block against the breech of the barrel in the closing movement, which action must be common to all forms of guns.

Were it possible to fit a bolt into a sleeve as tightly as I have here suggested the fitting of the link-pins, the bolt would be quite immovable with the amount of energy at our disposal. The best practice is to make the bolt very loose and shaky in its sleeve. This is economy of manufacture, and though it gives plenty of room for dirt to enter, yet also gives plenty for it to leave by. However, the loose fitting of the bolt leads to inaccuracy of shooting, due to irregular whip action, and varying trigger pull, and occasionally to difficulty of extraction, due to twisting or damag ing of shell from its not being regularly and thoroughly supported. This at best is only a means of lessening within a fixed limit, a fault inseparable from the sleeve method of construction.

In a majority of automatic guns, a link action, usually a form of toggle, is used as the power medium. There can, therefore, be no objection raised to it for this purpose; indeed, it is very generally looked upon as the best means yet used. The influences affecting a link action when used solely as the power medium, on a breech-block sliding in ways or a sleeve, likewise affect to the same extent a similar link action acting *both* as driver and guide to a freely moving block. If, therefore, abuse be given a gun of each of these types, the first one will offer the resistance of both link-work and the sliding-block, whereas the second will offer only that due to the link-work. Since I estimate that the resistance to the sliding of the block under varying conditions, and with various constructions, will average, at the lowest, four times that of the link-work, the ratio of resist-

ance between the two types is at least five to one in favor of the link-guided action. Furthermore, the link-guided action would be, generally speaking, cheaper to manufacture, and should allow less rattle and shake to the block.

In order to have the maximum of energy available at any instant to overcome abnormal resistance, it is necessary that the movement of every part should be a function of the movement of every other part. Consider a case in which this principle is not applied—that of the Mauser recoil-operated pistol, for instance. In this arm the block is securely locked to the barrel during a period of recoil, calculated to be sufficiently long to ensure the bullets having left the barrel before the breech is unlocked. During the first period of recoil the barrel and block together move at the same velocity, and since the comparative weights of the barrel and block are about as five to one respectively, the total available energy of recoil stored in them is divided between them in the same proportion. After the unlocking movement, the barrel abuts against a cushion and comes to rest, the block continuing its rearward movement by virtue of the energy stored in it, and with this operates the gun. Thus five-sixths of the total recoil energy is entirely wasted as far as the important operations of extraction, ejection, cocking and insertion are concerned. This is a most important weakness of this arm and is the source of many failures to operate.

There is as yet no recoil-operated arm in which the entire energy taken from the explosion is available for operating at all points in the cycle, but the well known Maxim machine gun and the Borchardt automatic pistol conform to this demand for the first half of the cycle. Take for example the Borchardt pistol (which is but a modified Maxim gun on a small scale). Its operation is roughly as follows: The block is locked home by a toggle joint attached at the rear end to a continuation of the barrel, and at its front end to the block. This constitutes the recoiling system, which slides to the rear in the grip piece, which may be likened to the carriage of a cannon. During the recoil, an arm projecting rearwardly from the rear link of the toggle

is forced downward by contact with a curved surface attached to the stationary grip, thereby raising the central joint of the link and drawing back the block. A long spiral flat spring is so placed as to resist both the recoil and the breaking of the toggle-joint, and at the end of the recoil this spring forces the barrel home and closes the breech, independently of one another.

During the recoil it is plain that if, for any cause the action is prevented from opening, the recoil motion must cease, and that therefore before an obstruction can succeed in stopping the mechanism it must offer sufficient resistance to absorb all the energy acquired by the various pieces from the recoil.

On the other hand, during the return home the movements of the breech-block and barrel are not functionally dependent on one another, and an obstruction to the block's movement is not acted upon by the energy stored in the barrel, which continues home without regard to the position of the mechanism. It is plain that energy stored in springs is not available for overcoming the irregular, sudden resistances met with in automatic gun practice, to such an extent as that stored as energy of movement in the mechanism itself. To give up a given amount of the energy stored in it, a spring must expand a certain amount; if it cannot expand this amount it cannot give up its latent energy. Energy in the form of $M. V^2$ is however available with an infinitesimal movement of the part in which it is stored, and it is therefore instantly expended to overcome resistances offered to the movements of the part. This feature, though not possessed to the full amount by any existing recoil gun, yet is common to nearly all forms of gas operated arms, and in my opinion has been one of the chief factors in the comparative success of the latter-type of arm.

A further consideration of small-arm design is that of the magazine. For military use this factor is of extreme importance. For the sportsman a magazine with which he can fire six shots in a few seconds, but cannot fully reload again inside of a minute, is far superior to a single shot rifle with which say thirty shots could be fired within the minute.

But, for the soldier, the second arm would be a more efficient weapon. In other words, it is a rapid continuous fire; rapidity for say 150 shots, which is desired, rather than extreme rapidity for six or ten, though this is also important. For military use, then, the ability to recharge the magazine quickly is of paramount importance, whereas for sporting purposes it is but a secondary consideration.

The ideal magazine for both uses would combine the following points: It should be chargable by single cartridges, or by clip or packet loading, in all positions of the mechanism, and particularly in the "ready-to-fire" position; there should be no lost movement for opening or shutting a trap, as in the Krag-Jörgensen; the magazine should be positive, that is, its operation should not be dependent on a spring; and finally, a single cartridge placed in the magazine should be fed into the chamber by one cycle of operation of the gun. This last consideration is in opposition to a magazine of the Spencer positive type in which, starting with the magazine empty, a cartridge being inserted, the mechanism must be operated as many times as the cartridge capacity of the magazine, before the cartridge enters the chamber. If to these could be added the feeding of cartridges from a belt, the ideal magazine would be attained.

In automatic small-arms, especially in one with a magazine of the above description, a cut-off for reserving the magazine and allowing single-shot fire would be unnecessary. Single-shot fire could be obtained by firing single shots semi-automatically, that is by always releasing the trigger before the second shot, and loading one cartridge into the magazine between each shot. This would give the fastest possible single-shot fire and would keep a full magazine in reserve for emergencies. A cut-off could be used where it is deemed advisable to *compel* slow firing.

One of the debatable problems of machine gun service remains the method of introducing the ammunition into the gun. There are three distinct solutions of the problem: the belt-feed; the drum, or hopper-feed, and the strip-feed.

Their features may be roughly summed up as follows: The belt-feed is probably the most satisfactory, owing to

the ease of manipulation, ability to fire continuously for a great number of shots, lightness, protection to ammunition, and compactness in packing. Its disadvantages are the necessity of more complicated feeding mechanism in the gun, liability to be affected by moisture, and the fact that the cartridges are not usually as securely held as to prevent their occasionally becoming displaced, causing interruption in firing. The Maxim and Colt guns both use the belt-feed.

The strip-feed, being necessarily made in small units, cannot be so easily manipulated, nor can the firing with it be as continuous without an extra man for feeding. It does not protect the ammunition so well as the cloth belt, but it is light, can be packed compactly, and allows the gun mechanism to be greatly simplified. The Hotchkiss gas-piston gun is fed by strips.

The drum, or hopper, feed does not seem to have found favor with designers of automatic guns, though for crank guns it has long been standard. The positive drums, such as the Accles, are bulky and heavy, while the gravity hopper-feeds are uncertain, especially in high-angle firing, one of the first duties of the machine gun of the future. The Carr gun feeds from a gravity drum and the Skoda '93 model from a gravity hopper.

[*To be concluded.*]

ROTARY TRANSFORMERS:

THEIR HISTORY, THEORY AND CHARACTERISTICS.

BY GEORGE W. COLLES, A.B., M.E.

(*Concluded from vol. cli, p. 445.*)

FREQUENCY TRANSFORMATION.

We have now spoken at length of three of the four main kinds[82] of current transformation, so far as they are or may be accomplished by rotary transforming apparatus, to wit,

[82] See page 209 (March uumber of this *Journal*).

the transformations of species, pressure and phase; it remains to speak briefly of frequency transformation. We shall, however, find very little to say on this subject, because this is a comparatively new and untried field as yet.

Apart from the universal motor generator method, we may outline three general methods or types of apparatus for transforming frequency, the first of which is entirely general, and the other two of limited application and scope. (We do not speak here of the production of high frequency currents, such as are used in induction coils and for producing electric waves, as a matter apart from the subject here considered.) As heretofore observed (page 210*), all apparatus hitherto known for transforming frequency involves moving parts.

In the first or general case just mentioned, the frequency transformation is considered as a generalization of the common *D C* transformation, the latter being, mathematically speaking, an alternating current of zero frequency. If we take a common *D C* generator and rotate the brushes, we shall, of course, obtain an approximately sinusoidal electromotive force, and consequent current, of a frequency corresponding to the ratio of rotation: and, extending this to rotary transformers of any kind, instead of having the brushes stationary upon the *D C* side, we cause them to rotate at the proper speed to give currents of the desired frequency. Three-phase and four-phase (two-phase) currents would, of course, be obtained by three and four brushes respectively, and so on. The desired rate of rotation may be obtained from a separate alternating donkey-motor working synchronously with the primary, and driving the rotating brushes either direct, or, if the ratio of transformation is not a simple one, through the medium of gearing, or it might be obtained through proper gearing from the main shaft of the transformer itself.

This method was first pointed out by Rowland in his patent above referred to (page 436). Obviously it is applicable to any machine provided with a commutator.

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* March number of this *Journal*.

The main practical objection to this method, however, would appear to be great, if not actually insuperable—the common one of sparking. We know that such rotation of the brushes, on a common closed coil *D C* generator, as a means of producing an alternating current, would be wholly impracticable—would, in fact, if any considerable current were drawn from the machine, be productive of violent internal reactions, in addition to the sparking. And we can hardly suppose that the results would be any more favorable on a rotary transformer, where the difficulties with stationary brushes are enough for us to contend with, and often only too great to make a wholly satisfactory machine.

Superadded to this, in the common one-coil rotary transformer, are the two other great objections, first, that it is necessary to just double the complication—to have *two* rotating shafts and *two* sets of slip-rings, instead of one; and, second, the rotating brushes. This latter may be avoided in machines of the inductorium type, because we are not restricted to any particular speed of the rotating commutator, and we may accordingly rotate it at a speed different from that corresponding to continuous current. Yet it is in just these machines that the sparking difficulty is greatest.

This same principle has been applied in a machine invented by Elihu Thomson,[83] wherein the secondary brushes of a dynamotor are made to rotate slowly backwards, so as to produce an alternating current of very low frequency (four cycles per second), adapted to operate reciprocating drills.

The second method of transforming frequency is that embodied in the machines devised by Lieut. F. J. Patten, and hereinbefore referred to (page 273*). These were first brought to public notice by him in 1892, in a paper read by him before the American Institute of Electrical Engineers,[84] and improved forms were shown in 1895[85]. To un-

[83] Patent No. 485,669, of November 8, 1892.

* April number of this *Journal.*

[84] Trans. Am. Inst. Elec. Engs., Vol. 9, p. 66, Feb. 16, 1892.

[85] *Elec. World*, Vol. 26, p. 669, Dec. 21, 1895.

derstand the method we first have reference to the simple form shown in Plate XXVII, *Fig. 1*. Between the poles *NS*

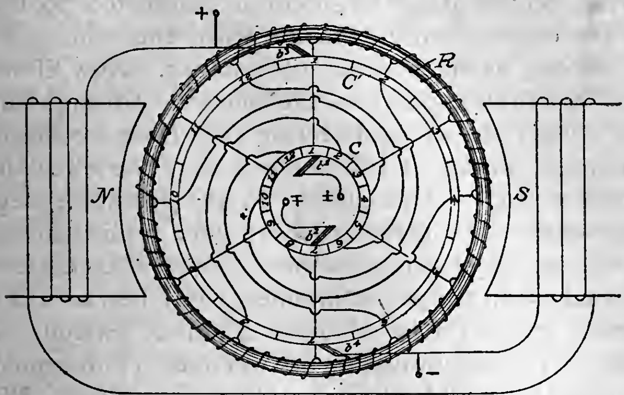

Fig. 1.

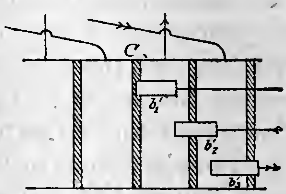

Fig. 3.

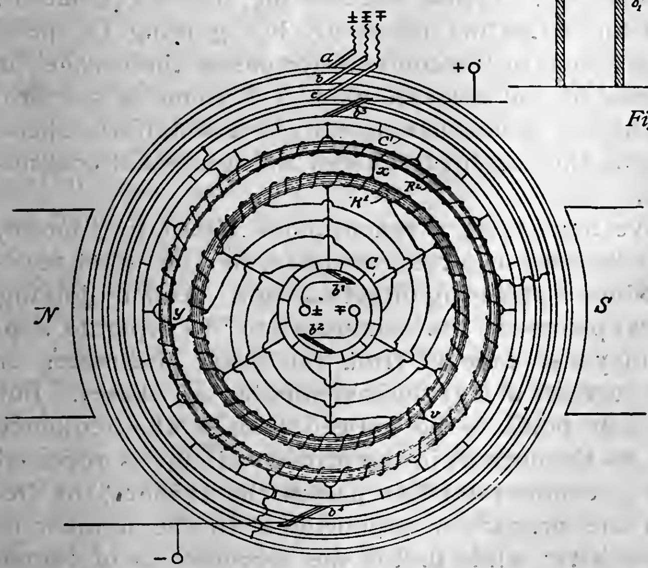

Fig. 2.

PLATE XXVII.—Patten's frequency transformer. 1892.

is placed an ordinary Gramme-wound ring *R*, connected to an ordinary commutator *C* at the centre, provided with the

brushes b^1 b^2; but, instead of the ordinary connection between the commutator segments and those of the ring, every alternate commutator segment is connected to the ring at a point diametrically opposite, while the others are directly connected, as in the ordinary manner. Now, if we suppose the current supplied to the machine through the brushes b^1 b^2 to be reversed in direction each time a commutator segment is passed, it will be seen that the effect as regards the direction of the current in the armature segments is the same as if a direct current were applied to the brushes b^3 b^4 of the outer commutator C', which is connected up to the armature in the usual manner. Further, an alternating current applied at b^1 b^2 gives a direct current at b^3 b^4, or rather a current pulsating between zero and a positive maximum, the machine thus acting as a rectifier. We may now, as shown, connect the brushes b^3 b^4 to the field winding and the machine becomes self-exciting. Thus connected the machine is also self-starting, like a *D C* motor, both field and armature reversing, but gaining in speed until one segment of the commutator passes the brushes at each reversal of the current, when it becomes a synchronous alternating motor, having a fixed and uniform speed depending on the current frequency and number of commutator bars.

We have here, then, a synchronous alternating motor, which may be used as a rotary transformer, or rather rectifier, to produce a pulsating direct current. And by joining symmetrical points on the commutator C' to separate slip-rings, we may also take off from the latter alternating or polyphase currents of any desired number of phases. But the important point to be noticed here is the frequency relation. As the current in the primary circuit is reversed each time a commutator bar passes the brushes, the frequency in the primary is proportional to the number of commutator bars; while that in the secondary is of course proportional to the number of poles. Thus with twelve commutator bars and two poles, as shown in the diagram, *Fig. 1*, the frequency relation is 12 : 2, that is, the frequency of the secondary circuit is reduced in the ratio of 1 : 6.

Of course, however, the alternating currents so produced would be of a very ragged and uneven character. In order to avoid or soften the pulsations in the secondary circuit, the inventor introduces the more complicated form shown in *Fig. 2*, in which two coils are wound on the same core, one of which is connected to the primary commutator, the other to the secondary commutator or slip-rings; the two coils being each Gramme-wound and connected to each other at three symmetrical points x, y, v. In the figure these two coils are for the sake of clearness shown as wound on separate cores. Here a, b, c represent the secondary slip-rings connected to give a three-phase circuit.

In case of a polyphase primary, in place of an alternating, as hitherto supposed, the same machine may be employed, the only change being in the brushes b^1 b^2, which are each replaced by two or more brushes, according to the number of phases. The terminals of the stationary transformers are kept separate, so that, for instance, for a three-phase primary we have six brushes, the two brushes belonging to each phase being diametrically opposite each other on the commutator, while the relative position of the brushes belonging to the three phases is shown in *Fig. 3*, the brushes being staggered or set one behind the other and separated by a distance equal to two thirds the width of a commutator segment.

It is not necessary in this type of machine to reduce the frequency in the ratio of the number of poles to the number of commutator bars, as such ratio is generally a high one, too high to be serviceable in practice. Instead of reversely connecting every alternate commutator segment, as shown in *Fig. 1*, we may group them in sets of three, four, or more, as desirable. Thus, suppose we have a machine with four poles and 112 commutator segments, and it is desired to reduce the frequency in the ratio of 1 : 4. We then require $4 \times 4 = 16$ reversals of current at each revolution in the secondary circuit, and as 16 is contained 7 times in 112, we directly connect the first 7 commutator segments, then reversely connect (*i. e.*, to the armature connections on the opposite side of the armature) the next 7 segments, and so on.

There is, however, one practical difficulty in the motor thus far described. It will be seen that at the point of reversal in the primary commutator, owing to the direct and reversed connections, the brushes b^1 b^2 will invariably be short-circuited, owing to the practical impossibility of causing them both to cross from one segment to the next at exactly the same instant; unless the alternative be taken of making the insulation between the commutator segments so wide as to open the circuit for a moment at reversal. As it is, of course, practically impossible to cause the reversal to take place at the mathematical zero point of the current, either alternative causes violent sparking and strain upon the insulation of the circuit. This difficulty is completely overcome by Lieutenant Patten in a later form of machine—though with considerable additional complication—by winding two armature coils in parallel, which are caused to alternate with each other in receiving the current from the brushes, in such manner that there is always sufficient length of wire between the two commutator segments on which the brushes may happen to be to avoid a short circuit, and at the same time there is no necessity of opening the circuit, during commutation.

This type of machine appears to possess great practical merits, along with a versatility surpassed by no other form. According to the statement of the inventor, many machines of this type have been built and in operation, of various forms, and they have worked satisfactorily.

The third and last method of transforming frequency which we shall consider is that due to Steinmetz [86] (Plates XXVIII and XXIX). Referring first to Plate XXVIII, we have at C the field and at S the armature of a three-phase induction motor M. The armature S drives, through the belt B, the armature of an equal machine G, so as to produce three-phase currents; and its own armature, instead of being closed on itself or short-circuited, is carried out into a three-phase external circuit a' b' c' and there made to supply lamps and motors. Now the sum of the

[86] Patents Nos. 620,986, 620,987 and 620,990, of March 14, 1899.

frequency in the circuit a' b' c' of the motor armature and that of the generator armature a^2 b^2 c^2—assuming these two

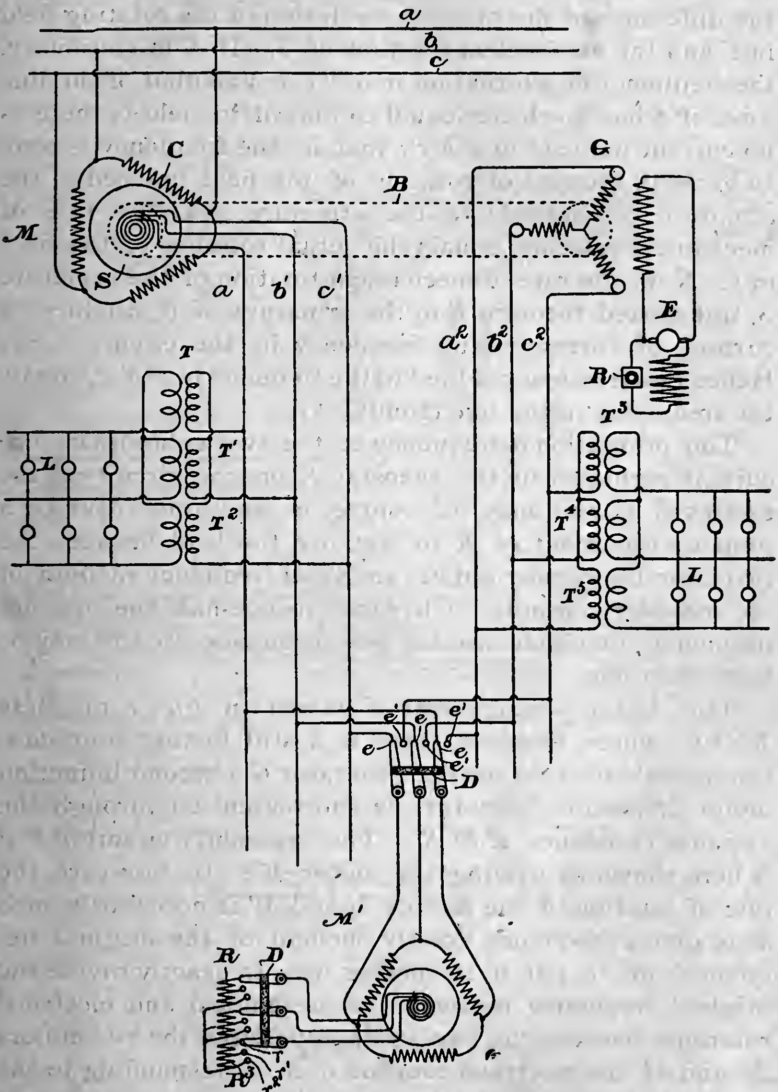

PLATE XXVIII.—Steinmetz's method of frequency transformation. 1899. (First form.)

machines to be alike—is equal to the primary frequency on the supply line a b c.

To understand this, consider that the frequency of alternation in the motor armature is equal to the slip—that is, the difference of the rates of revolution of the rotating field in C and the mechanical rotation of S. If S is stationary, the frequency of alternation in $a' \, b' \, c'$ equals that of the line $a \, b \, c$; if S has a velocity equal to that of its field C, there is no current induced in $a' \, b' \, c'$; that is, the frequency is zero. In general, the rate of rotation of the field induced in the armature S *relatively* to the armature, *plus* the rate of mechanical rotation, equals the actual rotation of the field in C. Now, the rate of mechanical rotation of the armature S, transferred through B to the armature of G, produces a current of corresponding frequency in the circuit $a^2 \, b^2 \, c^2$. Hence this frequency, added to the freqency in $a' \, b' \, c'$, equals the frequency in the line circuit $a \, b \, c$.

The proportional frequency of the two subordinate circuits is regulated by the rheostat R on the circuit of the exciter of G, and may, of course, be anything. But by a proper adjustment of R to equalize the load between the two circuits, we may obtain an equal frequency in both of the secondary circuits, each equal to one-half the original frequency; in which case the two secondary circuits may be fused into one.

This latter arrangement is shown in *Fig. 1* of Plate XXIX; where, however, there is a still further simplification in substituting for the generator G a second induction motor M', whose armature is short-circuited through the variable resistance $R \, R' \, R^2$. The secondary circuit $a' \, b' \, c'$ is here shown as driving the motor M^2. In this case the rate of rotation of the motors M and M' is necessarily such as to give a frequency exactly one-half of the original frequency; or, to put it in another way, to exactly divide the original frequency between the mechanical and electrical rotations, because the two are transposed in the two motors M' and M, the electrical rotation of M corresponding to the mechanical rotation of M', and *vice versa*. Any change will cause a difference of frequency between the secondary circuits of M and M' to be set up, and tend to re-establish equality; so also with the mechanical work done, the work

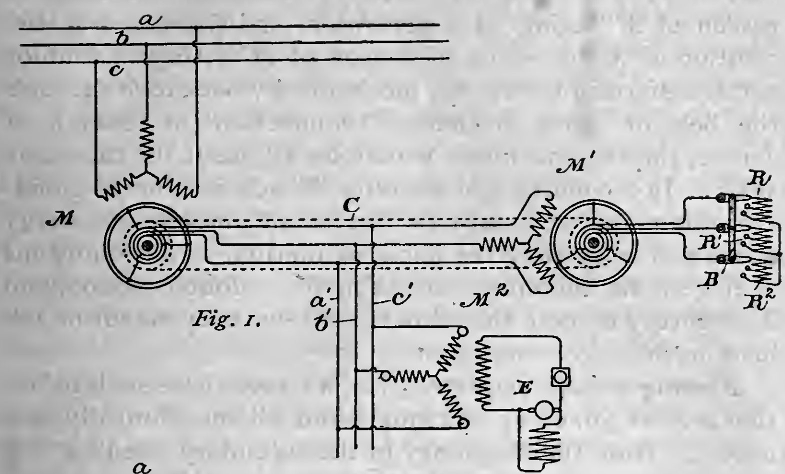

Fig. 1.

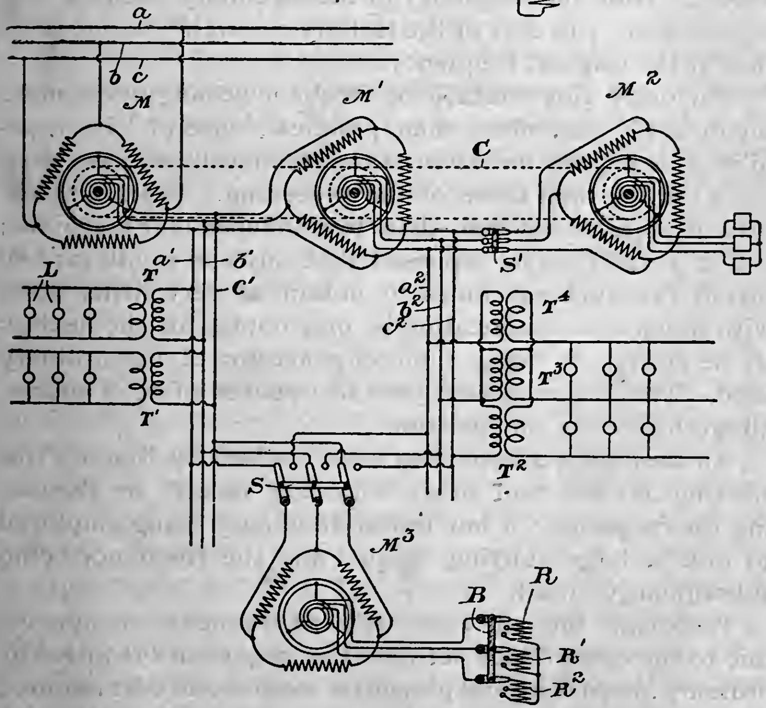

Fig. 2.

PLATE XXIX.—Steinmetz's method of freqency transformation. 1899.
(Second form.)

thrown upon M being increased if the rotation increases by reason of M' acting as a generator; and decreased if the rotation of M decreases, by reason of M' acting as a motor and transferring the energy mechanically back to M through the belt or other mechanical connection (in general, of course, the two machines would be adjacent on the same shaft). In a condition of stability M' acts neither as generator nor as motor, except for the small amount of energy consumed in keeping the parts in motion. The conditions of the circuit, therefore, are stable for a double reason, and it is worthy of note that this is entirely independent of the load on the secondary circuit.

Passing a step further (*Fig. 2*), we have three such induction motors joined up in tandem and all mechanically connected. Here the frequency in the secondary circuit $a' b' c'$ is two-thirds, and that of the tertiary circuit $a^2 b^2 c^2$ one-third that of the original frequency.

Obviously this method of frequency-changing is more theoretically ingenious than practically useful. Its capabilities as regards variation of the frequency ratio are even more limited than those of the preceding. In its simplest form it requires not less than two independent machines; and it is hardly to be supposed that any one would care to install two such machines to obtain so very little, when with much less complication he may obtain all the flexibility he desires by using a motor-generator of the ordinary kind. The three-machine form last spoken of is, of course, altogether out of the question.

An analogous scheme has been devised by Bradley[87] for starting railway and other induction motors by regulating the frequency; a low initial frequency being employed to give a large starting torque, and the frequency being subsequently raised.

Practically the only *raison d'être* of frequency changers is due to the discordance between the frequencies required by ordinary alternating and polyphase motors, and that required for lighting, or rather for economical transformation by

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[87] Patents Nos. 615,673, 615,953 and 615,954 of December 13, 1898.

stationary transformers. The be-all and end-all of their existence is to enable low-frequency motors to be run from high-frequency circuits. Now if to attain this end we must start by obtaining *another* motor big enough to convert all the current to be used by our original motor, and able to run from the high-frequency circuit—we commit a clear absurdity—a fatuity—nay, a *petitio principii*—for we started with the assumption that we should not use a high-frequency motor. Yet this is all the inventors of frequency-changers have done for us—if we except Rowland's idea as applied to machines of the inductorium type, which scantly escapes the accusation, and, as we have seen, labors under another scarcely less vital. We may, therefore, at once dismiss from our consideration all the plans for frequency-changing hitherto devised as valueless for practical work—at least in ninety-nine cases in a hundred.

If a frequency-changer cannot be devised without the use of a motor running at the higher frequency, it had better not be devised at all. What the art really calls for is a *stationary* frequency-changer—one without moving, at least without rotating parts; though on what principle we should start to devise such a machine it is difficult to see. Certainly it must be in a direction radically different from anything hitherto thought of.

CONCLUSION.

The great problem, whose solution forms the main thesis of this essay—to construct a machine to satisfactorily perform *any* necessary or desirable transformation, however complex—is seen to be as yet but very imperfectly solved. In only four cases—transformation of the pressures of direct currents, transformation of the pressures of alternating and polyphase currents, transformation of the phases of polyphase currents, and transformation between polyphase (or alternating) and direct currents—can we be said to have reached a satisfactory solution; in the first and last of these, "satisfactory" means only, as satisfactory as there is any prospect of getting. Complex transformations are in general difficult and unsatisfactory, requiring more than one

machine. The new type herein called the inductorium offers, however, great hope for the future as regards most of the requirements of electrical energy. As regards frequency transformation, however, so far as practical results are concerned, the art stands where it did in the beginning.

One fact stands out clearly: that practically, the only *raison d'être* of the rotary transformer, dynamotor, motor-generator and all, is the continuous current. Were it not for the continuous current, they would probably have no existence; for wherever only alternating and polyphase currents are concerned, we can at least get along without them, and, except possibly in the *A C–P P C* transformation, most satisfactorily so. Some—the continuous current advocates—by a queer reversal of logic, would lay the blame for this state of facts upon the alternating, instead of on the continuous current where it belongs. Clearly, wherever we have continous-current machinery, there is the ever-present commutator, with all the ills that it is heir to, and that follow in its train—sparking, short circuits, open circuits, overheating, friction, wear, and a delicate sensitiveness to anything like high pressures—and, of course, moving parts. It is vain and useless to speak of the feasibility of continuous current at high pressures; we know that, whatever, according to some, *might* be done, the only fair standard is what *is* done. We know by experience, too, that, whatever we might *a priori* assume, moving parts in electrical machinery—particularly where a commutator is concerned—cannot long be left without supervision. When we have, superadded to the commutator (as in some forms of transforming apparatus) such a thing as *rotating brushes*, the practical difficulties and inconveniences are so great that perhaps 90 per cent. of engineers would prefer any number of slip-rings to even *two* of them. So we have, in the Hutin-Leblanc machine, for instance (page 440), as an alternative to the rotating brushes, a shaft with *forty-eight slip-rings!*

Consider now the matter more fundamentally. In these days when induction plays so great, so all-important a part in electrical engineering, the continuous current labors under the disadvantage of being able to induce nothing

unless by the motion of the circuit itself—which implies mechanical motion. And mechanical motion implies, practically, a commutator and its failings.

Stationary transformation of continuous currents appears for like reasons impossible. By no conceivable method could alternating currents be superposed so as to produce a continuous current; because the *algebraic average* of the strength of every alternating current is zero, and the algebraic sum of several must be likewise zero, while the average strength of a continuous current is, of course, a finite quantity. So far as the pole-changing and rectification methods are concerned, they have, as herein pointed out, proved weak and futile.

Heavily handicapped as it is with its ever-present commutator, the continuous current, as contrasted with the other forms, might be compared to a delicate child. It must never go out in the rain, must be careful not to get overheated, and its strength will not permit it to journey far from home; while at best its life (that of the commutator) is but a short one. But its *good disposition*, *harmlessness*, and greater *adaptability* keep it in favor.

The alternating current, on the other hand, might be compared to a giant, capable of herculean labors, though somewhat rough, crude and untrained in the finer operations of the arts as yet; of a somewhat uncertain and at times dangerous disposition.

It seems clear that, in the vast undertakings of to day, where the keynote is the *transmission of power*, it is the giant rather than the child of which the world has greatest need. It is possible that the giant may be trained to the docility and susceptibility of the child, but certain that the child cannot be given the strength of the giant.

It does not seem, therefore, to the present writer that the continuous can ever supplant the alternating current for all or even most purposes, as contended by its advocates. And, on the other hand, there are certain cases, in particular electroplating and electrochemistry generally, where the continuous current seems the only one available. Probably we shall continue to need them both, in spite of all our inge-

nious plans to dispense with one or the other. And as long as we need both, so long shall we need to transform one into the other. And as long as we have need of transforming machinery for this purpose, so long, as now made clear, shall we need *rotary* transformers. The art, therefore, which we have just surveyed is not to be considered a transitory one.

ANTARCTICA: A HISTORY OF ANTARCTIC DISCOVERY.*

By Edwin Swift Balch.

(*Concluded from p. 428.*)

III. VOYAGES SUBSEQUENT TO THE DISCOVERY OF A SOUTH POLAR CONTINENT.

The year after Wilkes and D'Urville comes another expedition, that of Sir James Clark Ross,† which confirms the belief that south of Australia is a continental mass of land. The expedition was decided on, in acquiescence to a series of resolutions adopted by the British Association, in August, 1838,‡ and the instructions to Ross from the Lords Commissioners of the Admiralty were dated the 14th day of September, 1839.§ Ross knew all about Wilkes' cruise and the discovery of the Southern Continent before he sailed from Hobart Town, for he had received a long letter from Wilkes on the subject || and also a rough chart. Ross

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† Ross, Captain Sir James Clark, R. N.: "Voyage of Discovery and Research in the Southern and Antarctic Regions," during the years 1839-43; London, John Murray, 1847.

McCormick, R., Deputy Inspector General, R. N., F. R. G. S.: "Voyages of Discovery in the Arctic and Antarctic Seas," etc., London, Sampson Low, Marston, Searle and Rivington, 1884.

‡ "Voyage," etc., Vol. I, page v.

§ "Voyage," etc., Vol. I, pages xxi-xxviii.

|| Published in Wilkes' "Narrative," etc., Vol. II, pages 453-456, and also in Ross' "Voyage," etc., Vol. I, pages 346-352.

speaks of the action of Wilkes in the following terms:* "I felt therefore, the more indebted to the kind and generous consideration of Lieutenant Wilkes, the distinguished commander of the expedition, for a long letter on various subjects, which his experience had suggested as likely to prove serviceable to me * * * and I avail myself of this opportunity of publicly expressing the deep sense of thankfulness I feel to him for his friendly and highly honorable conduct."

Nevertheless Ross seems to have considered that Wilkes should not have made a cruise to the Antarctic when he, Ross, was coming, for he says: † "That the commanders of each of these great national undertakings should have selected the very place for penetrating to the southward, for the exploration of which they were well aware, at the time, that the expedition under my command was expressly preparing, and thereby forestalling our purposes, did certainly greatly surprise me." This statement is certainly surprising. Ross' expedition only had its *inception* in August, 1838, the very month in which the instructions of the Government of the United States were issued to Wilkes, and in obedience to which he made his cruise to the Antarctic: ‡ facts which Ross must have known when he published his book in 1847, as Wilkes had published his book in 1845, and Ross had seen it.

Ross sailed from Hobart Town on November 12, 1840. He selected the meridian of 170° east, "on which to endeavor to penetrate to the southward. * * * My chief reason for choosing this particular meridian in preference to any other was, its being that upon which Balleny had in the summer of 1839, attained to the latitude of sixty-nine degrees, and there found an open sea."§ His ships, the "Erebus" and "Terror," having been thoroughly strengthened, were much more suitable for ice navigation than those of Wilkes or D'Urville. In consequence, he was

* "Voyage," etc., Vol. I, pages 115, 116.
† "Voyage," etc., Vol. I, pages 116, 117.
‡ See *ante*.
§ Ross: "Voyage," etc., Vol. I, page 117.

able to break through the pack, and on January 11, 1841, in 71° 15′ south latitude, "A strong 'land-blink' made its appearance* in the horizon as the ships advanced, and had attained an elevation of several degrees by midnight. All of us were disposed to doubt that which we so much apprehended, owing to its much paler colour than the land-blinks we had seen in the northern regions, but soon after 2 A.M. the officer of the watch, Lieutenant Wood, reported that the land itself was distinctly seen directly ahead of the ship. * * * It rose in lofty peaks, entirely covered with perennial snow; it could be distinctly traced from S. S. W. to S. E. by S. (by compass), and must have been more than one hundred miles distant when first seen. * * * The highest mountain of this range I named after Lieutenant-Colonel Sabine," etc.† The same day Ross christened Cape Adare and Admiralty Range, and the next morning he landed on Possession Island, in 71° 56′ south latitude, 171° 7′ east longitude, "composed entirely of igneous rocks, and only accessible on its western side."‡

Ross worked gradually south. On January 15th he named Mount Herschel; on January 17th Coulman Island; on January 21st, in 74° 15′ south latitude, he named Mount Melbourne; on January 27th he was in 76° 8′ south latitude, 168° 12′ east longitude, and landed on an island which he called Franklin Island. On January 18th, "we stood to the southward, close to some land§ which had been in sight since the preceding noon, which we then called the 'High Island'; it proved to be a mountain twelve thousand four hundred feet of elevation above the level of the sea, emitting flame and smoke in great profusion: at first the smoke appeared like snow drift, but as we drew nearer its true character became manifest. * * * I named it 'Mount

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* "Voyage," etc., Vol. I, page 183.

† "This statement of Ross of seeing the "land-blink" at a distance of over 100 miles is interesting, for it proves that Lieutenant-Commander Ringgold may have seen the "loom over high land" over the Balleny Islands on the 13th of January, 1840, on which date he was almost exactly two degrees of latitude north of them. See *ante*.

‡ "Voyage," etc., Vol. I, page 189.

§ "Voyage," etc., Vol. I, pages 216, 217.

Erebus,' and an extinct volcano to the eastward, little inferior in height, being by measurement ten thousand nine hundred feet high, was called 'Mount Terror.'" The eastern cape at the foot of Mount Terror was named "Cape Crozier" and another mountain, a little further south, "Mount Parry."

Ross christened this land "Victoria Land," "whose continuity we had traced from the seventieth to the seventy-ninth degree of latitude."* The coast line of Victoria Land must surely be a continuation of the coast line of Wilkes Land, and as, to make a land, there must be some extension in breadth beyond the coast line, and as the extension of Ross' coast is due south of Wilkes Land, and only some 3 or 4° of latitude distant, the land mass sighted by Ross, therefore, even if the whole place is an archipelago, must be a portion, a *hinterland*, of the land mass sighted by Wilkes.

From the great volcanoes, Ross cruised eastward, reaching his most southerly point, 78° 4′ south latitude, on February 2d; and his most easterly point, 77° 18′ south latitude, 167° west longitude, on February 5th. During this part of the trip, the ships coasted along a perpendicular barrier of ice, some 45 to 60 meters high and more than 700 kilometers long. Ross then started northward, and on the 21st his vessels were again near Cape Adare. They kept on north, and on March 4th, passed well to the eastward of the Balleny Islands, being in 66° 44′ south latitude, 165° 45′ east longitude.† Ross then sailed northward and westward; on March 6th he was in 64° 51′ south latitude, 164° 45′ east longitude, and on March 7th in 65° 31′ south latitude, 162° 9′ east longitude. He then sailed further westward on a track some two degrees north of the track of Wilkes. *He was, therefore, first too far east, then too far north, to see any of the lands sighted by Wilkes himself*, as the South Polar Chart, in the second volume of Ross' book and which gives his track, conclusively proves.

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* "Voyage," etc., Vol. I, page 248.
† "Voyage," etc., Vol. I, page 269.

Ross states, however, that he sailed over a spot, about northeast of the Balleny Islands, which was charted as land on the chart sent him by Wilkes; and on the strength of this only, he did not lay down Wilkes' discoveries on his South Polar chart. Ross devoted many pages of his book to this matter, on which some English geographers lay much stress, and it is necessary, therefore, to discuss it rather at length, and to point out how Ross is in error.*

That Wilkes was justified in laying down this land is evident, for the following reasons: On the chart of the Antarctic Continent, published in the first volume of Ross' book in 1847 only, the Balleny Islands are laid down by Ross himself.† Northeast of them a land is indicated, which is intersected by Ross' track. The chart also gives the position of the "Vincennes on the 13th, and a line drawn from this to the Balleny Islands goes almost through the centre of the land. As the "Porpoise" was close to "Vincennes" on the 13th, the line of vision, in which Ringgold saw the "loom over high land," went straight to the Balleny Isles, which undoubtedly were the cause of this loom.‡ On comparing the statement of Ringgold, with the reported discovery of Balleny, therefore, Wilkes must have considered that Ringgold's appearance of land and the Balleny Isles were the same; and he naturally laid them down on the chart, although a little too far north.

Ross himself quotes § the perfectly straightforward ex-

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* "Sir Clements R. Markham, K. C. B., P. R. G. S., in the ninth edition of the "Encyclopædia Britannica," 1884, article "Polar Regions," says: "At the same time Commander Wilkes of the United States expedition made a cruise to the southward and mapped a large tract of land in the latitude of the Antarctic Circle for which he claimed the discovery. But as a portion of it had been already seen by Balleny, and the rest had since been proved not to exist, the claim has not been admitted."

Mr. W. J. J. Spry, R. N., says ("The cruise of Her Majesty' Ship "Challenger," 1877, page 139): "The supposed existence of this continent was, to a certain extent, proved to be erroneous by Sir James C. Ross' expedition the following year sailing over two of the positions assigned to it."

† According to his own statement. "Voyage," etc , Vol. I, page 287.

‡ See *ante*.

§ "Voyage," etc., Vol. I, pages 286, 287, quoting Wilkes: "Synopsis of the Cruise of the U. S. E. E." delivered before the National Institute in 1842, pages 21 and 26. I have not seen this paper.

planations of Wilkes as to how this land came to be indicated on the chart: "During our cruise, as we sailed along the icy barrier, I prepared a chart, laying down the land, not only where we had actually determined it to exist, but those places in which every appearance denoted its existence, forming almost a continuous line from 160° to 97° east longitude. I had a tracing-copy made of this chart, on which was laid down the land supposed to have been seen by Bellamy (Balleny) in 165° E., which, with my notes, experience, etc., was forwarded to Captain Ross," etc. * * * "As I before remarked, on my original chart I had laid down the supposed position of Bellamy Islands or land in 164° and 165° East longitude, and that it was traced off, and sent to Captain Ross. I am not a little surprised that so intelligent a navigator as Captain Ross, on finding that he had run over this position, should not have closely inquired into the statement relative to our discoveries that had been published in the Sydney and Hobart Town papers, which he must have seen, and have induced him to make a careful examination of the tracks of the squadron, laid down on the chart sent him, by which he would have assured himself in a few moments that it had never been laid down or claimed as part of our discovery, before he made so bold an assertion to an American officer [Captain J. H. Aulick], that he had run over a clear ocean where I had laid down land; and I am not less surprised that that officer should have taken it for granted, without examination, that such was the fact." The fact that Wilkes tried to do justice to the Englishman, Balleny, by recognizing and putting down Balleny's discovery, is unnoticed by Ross. And that Wilkes' explanation is correct, is easily verified by the writings and the charts of the two explorers.

Wilkes in his "Narrative" makes no claim to have sighted any land until in 157° 46′ east longitude, that is several degrees *west* of the Balleny Islands. Even of that he was not quite sure at the time; in fact, not until the observations of the three vessels had been compared, and also because of the more positive proofs of the existence of land afterwards obtained. It was not until January 19th, in

154° 30′ east longitude, that he "was fully satisfied that it was certainly land." An absolutely indisputable proof that this is true is afforded by the article in the *Sydney Herald* of March 13, 1840, which says that the land was discovered on January 19th, and which twice mentions the longitude as 154° 18′ east. The charts published by Wilkes in 1845, tally exactly with the "Narrative." The most easterly land laid down is "Ringgold's Knoll" in 157° 46′ east longitude, that is, several degrees to the west of the Balleny Islands.

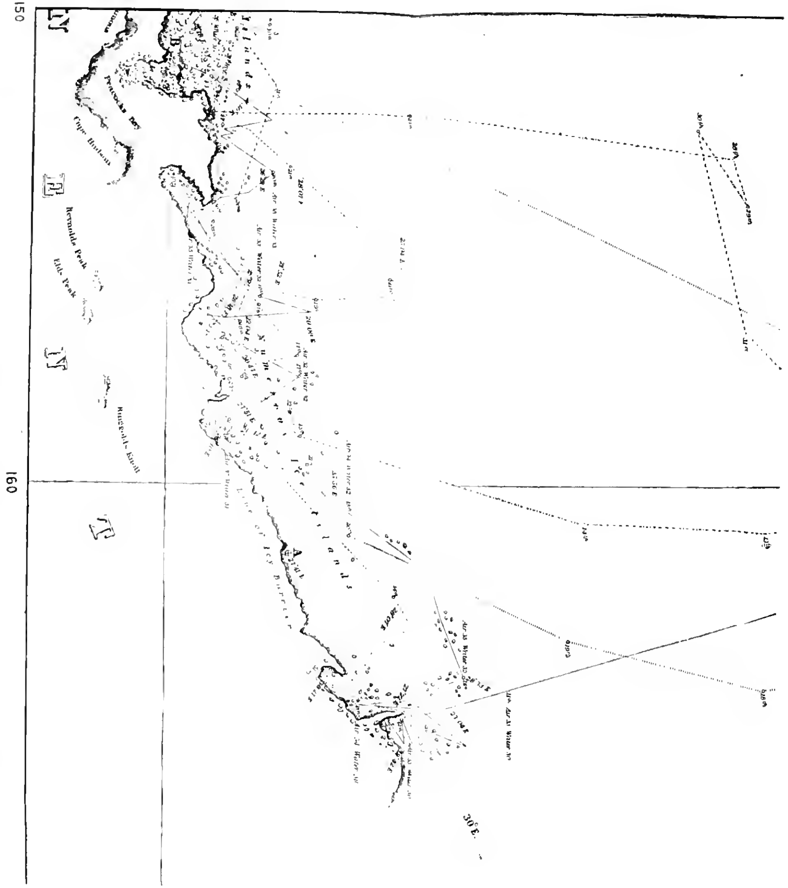
That Ross did not sail over any portion of Wilkes Land can be seen at a glance by comparing the charts of the two explorers. The most easterly land on the charts of Wilkes is well to the *west* of the Balleny Islands; while on the charts published two years later only by Ross, Ross' course is laid down to the *east* of the Balleny Islands, proving that he passed at least five or six degrees to the eastward of the extremest point of Wilkes Land. It would seem as though Ross must have known these facts when he published his book in 1847, for Wilkes had published his "Narrative" in 1845, and Ross mention it.* Still he paid no attention to either the "Narrative" or the charts of Wilkes. One thing at any rate is certain, and that is, that whether Wilkes' work is eventually proved or disproved, yet it may be asserted with absolute confidence that none of his discoveries were disproved by Ross, for the simple reason that Ross never was within sighting distance of any part of Wilkes Land.†

Ross ‡ sailed again from New Zealand on November 23, 1841. Icebergs were first seen on December 16th, in 58° 36′ south latitude, 146° 33′ west longitude. Ross en-

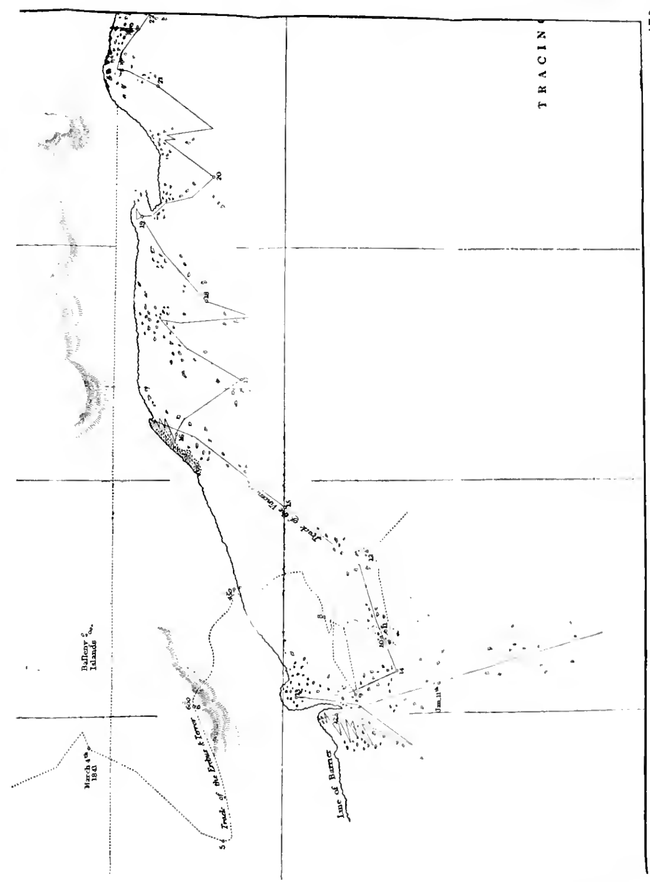
* "Voyage," etc., Vol. I, pages 116, 274, 295, etc.

† "The editor of D'Urville's "Voyage" complains forcibly of the treatment meted out to D'Urville in the report of Ross' cruise which he says was published in the *Literary Gazette* of September 16, 1843, and which he thinks either Ross or one of his officers must have written. The editor says ("Voyage au Pôle Sud," etc., Tome Huitième, page 230): "L'auteur de ce rapport, dans l'intention évidente de rapporter à son compatriote l'honneur de la découverte des terres australes, a commis une erreur volontaire et grossière."

‡ "Voyage," etc., Vol. II, pages 125–213.



Photographic reproduction of eastern portion of chart published by Lieutenant Charles Wilkes in 1841, showing that the most easterly land which the United States Exploring Expedition ... longitude.



Photographic reproduction of eastern portion of chart published by Sir J. C. Ross in 1847, showing that the northern track of the "Erebus" and "Terror" was eastward of 161° east longitude, and at least 100 miles distant from any part of Wilkes Land.

tered the pack on December 18th, in 60° 50′ south latitude, 147° 25′ west longitude. He worked his way through the pack until February 2d, when the ships were in 67° 29′ south latitude, 159° 1′ west longitude, where he found more open water. On February 9th the ships were in 70° 39′ south latitude, 174° 31′ west longitude. Ross kept working south and on February 16th was in 75° 6′ south latitude, 187° 4′ west longitude, reaching his most southerly point on February 23d, in 78° 10′ south latitude, 161° 27′ west longitude. He was then off the great ice barrier he had seen the preceding year. It averaged thirty meters in height above the water, and soundings in front of it in one place gave a depth of 290 fathoms. There was an "appearance of land" at this spot. Ross then returned, keeping along the edge of the pack until nearly 69° 52′ south latitnde, 180° longitude, when the ships ran into open water.

The following year Ross * sailed from the Falkland Islands on December 17, 1842. He met the pack on December 25th, in 62° 30′ south latitude, 52° west longitude. He worked south, and on the eastern coast of the western mainland, charted a large bay as "Erebus and Terror Gulf," and a high mountain as Mount Haddington. A little island east of this, in 64° 12′ south latitude, 59° 49′ west longitude, was named Cockburn Island. On this a small flora was obtained, which Dr. Hooker described.† There were nineteen species, mosses, algæ and lichens. Twelve are terrestrial, three inhabit either fresh water or moist ground, and four are confined to the surrounding ocean. All through January, 1843, Ross beat around in the pack to the east of these lands. He got clear of it on February 4th, when he sailed eastward to try to follow Weddell's track. Between the meridians of 10° and 20° west longitude, Ross pushed south, attaining on March 5th, 71° 30′ south latitude, 14° 51′ west longitude, when pack ice stopped him once more. He then sailed north, and on his return voyage searched in vain for Bouvet Island.

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* "Voyage," etc., Vol. II, pages 321–374.

† "Voyage," etc., Vol. II, pages 335–342.

Capt. William H. Smiley, an American master of a sealing vessel, made a voyage in 1842, probably west of Gerlache Strait. At Pendulum Cove, Deception Island, he found a self-registering thermometer, which was left there in 1829 by Captain Foster. Smiley wrote a letter to Lieutenant Wilkes, who says: * "Captain Smiley, who mentions in his letter to me, that in February, 1842, the whole south side of Deception Island appeared as if on fire. He counted thirteen volcanoes in action. He is of opinion that the island is undergoing many changes. He likewise reports that Palmer's Land consists of a number of islands, between which he has entered, and that the passages are deep, narrow and dangerous."

Lieut. T. L. Moore,† commanding the "Pagoda," sailed from Simons Bay on January 9, 1845. On the 25th, in 53° 30′ south latitude, 7° 30′ east longitude, he met the first icebergs. Then he sailed over the place where Bouvet Island was laid down on the charts, but could not see any land. In 60° 43′ south latitude, 3° 45′ east longitude, he fell in with a singular rock, or rock on an iceberg; the mass of rock was estimated at about sixteen hundred tons; the top was covered with ice and did not appear to have any visible motion, with a heavy sea beating over it; it had a tide-mark round it. On the evening of February 11th, in 67° 50′ south latitude (the highest latitude attained), 39° 41′ east longitude, Moore fell in with heavy pack ice, extending as far as could be seen from the masthead, and the weather becoming thick, he was obliged to work the ship off, being then only 70 miles from Enderby Land. Later they got within 50 or 60 miles, but saw no indications of land. W. D. says of this: "The ship was at one time within 80 miles of Enderby Land; but no indication of such proximity was visible. There were no icebergs nor blink, nor any observable change in the aspect of water or sky."

* "Narrative," U. S. E. E., Vol. I, pages 144, 145.

† "The Nautical Magazine and Naval Chronicle for 1846," London, Simpkin, Marshall & Co., pages 21, 22: "Magnetic Voyage of the 'Pagoda.'" Extract of a letter from Lieut. T. L. Moore, R. N.

"Colburn's United Service Magazine," London, 1850, Part II, pages 201, and the "Antarctic Voyage of Her Majesty's hired barque 'Pagoda,'" by W. D. The author's full name does not appear to be given.

The "Pagoda" continued on an easterly course, encountering comparatively little ice until 64° south latitude, 50° east longitude, where there was a strong ice blink. On March 6th they passed a chain of icebergs and loose ice, and the next morning the ship was surrounded by bergs and pack-ice behind which appeared a high ridge of ice or land, which could only be seen at intervals on the clearing up of the squall, and then only for a short time. From that time the ice got thicker every day; at times more than 100 bergs were seen in a day, one berg being 5½ miles in length and 45 meters high. On March 20th they were driven out of the 6th (*sic*) degree of latitude and 98° longitude by heavy ice, and the appearance of pack ice in the southeast, and thereupon stood northward. Lieutenant Moore says: "In this trip we passed more icebergs than in the three former trips, and likewise have run over more degrees of longitude, inside of sixty, than any ship has done before." The voyage of the "Pagoda" is noteworthy, because of the doubts it throws about the existence of Enderby Land.

Captain William Grant* in the "Day Spring," on December 23, 1855, in 56° 50′ south latitude, 40° west longitude, sighted an icy barrier of flat-topped icebergs, apparently about 120 to 150 meters high, and had some difficulty in extricating his ship from them. There were seldom less than ten or fifteen ice islands in sight until December 27th, in 52° 40′ south latitude, 20° west longitude.

Captain Dallmann,† a German, in the steamship "Groenland," was seal hunting from November 17, 1873, to March 4, 1874. On January 8th, in about 64° 45′ south latitude, Dallmann landed on one of the southern islands of Gerritz Archipelago. On January 10th he found a deep bay, where he appears to have landed in about 64° 55′ south latitude; this bay terminated in a strait which stretched away as far

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* Rosser, W. M.: "Notes on the Physical Geography and Meteorology of the South Atlantic," London, James Imray & Son, 1862, page 94.

†"Verhandlungen des Vereins für naturwissenschaftliche Unterhandlung zu Hamburg," Band V, Hamburg, 1883, pages 118–128, 130–136: "Die Entwickelung unserer Kenntnisse der Länder im Süden von America, vom Schiffskapitain A. Schück."

as the eye could see. The land appeared to consist of islands, for Dallmann saw several streaks of blue sky, which seemed as if they must be over straits. The land was high and mountainous, and the coast between the capes was filled with a high upright ice wall, from which large pieces frequently broke off. The strait has been called Bismarck Strait, but a better name would be Dallmann Strait; it is either the southern end of Gerlache Strait or a strait opening into it. Dallmann sailed north from this strait and came to the Shetlands and the Orkneys. He found all the charts extremely unreliable.

In 1874, Captain George S. Nares, R.N., in command of the "Challenger,"* on her deep-sea sounding and dredging expedition, after a stop at Kerguelen Island, sailed southeast and crossed the Antarctic Circle. On February 23, 24 and 25, 1874, the "Challenger" was on the outskirts of the pack, reaching 64° 18′ south latitude, 94° 47′ east longitude. The accounts of the different writers disagree in various minor respects, but they agree in stating that the pack was too heavy for an undefended ship to enter, and also that Termination Land was not sighted. The official account is that of Sir John Murray, who says: "After getting clear of the pack at 11 A.M. [25th] the ship sailed along its edge until noon, being from 10 A.M. until that time within about fifteen miles of the supposed position of Wilkes' Termination Land, but neither from the deck nor masthead could any indication of it be seen. The limit of vision as logged was twelve miles, and had there been land sufficiently lofty for Wilkes to have seen it at a distance of sixty miles (which was the distance he supposed himself off

* Report on the Scientific Results of the Voyage of H.M.S. 'Challenger': prepared by Sir C. Wyville Thomson and John Murray; London, 1885; "Narrative," Vol. I, pages 396–452.

Spry, W. J. J., R. N.: "The Cruise of Her Majesty's Ship 'Challenger.'" London, Sampson Low, Marston, Searle & Rivington, 1877.

Campbell, Lord George: "Log Letters from the 'Challenger.'" London, Macmillan & Co., 1876.

Wild, John James: "At Anchor, A Narrative of Experiences Afloat and Ashore during the Voyage of H.M.S. 'Challenger.'" London, Marcus Ward & Co., 1878, pages 59–78.

it) either the clouds capping it or the land itself must have been seen. If Wilkes' distance was overestimated, that of the "Challenger" would be increased, and it may still be found, but as the expression in Wilkes' journal is 'appearance of lands was seen to the southwest, and its trending seemed to be to the northward,' and not that land was actually sighted, and a bearing obtained, it is probable that Termination Land does not exist; still it is curious that pack ice and a large number of bergs should have been found in nearly the same position as by Wilkes in 1840, and this would seem to indicate that land cannot be very far distant."

It is worth noting that Wilkes only speaks of "an appearance of land" at this spot. The most important geographical result of the "Challenger's" southern jaunt, was to prove that there was a floating ice barrier in 1874 in exactly the same situation where there was a floating ice barrier in 1840.

In 1874–75* a party of American, another of English, and a third of German scientists, spent part of the southern summer on Kerguelen Island, principally occupied in making observations in connection with the transit of Venus.

In 1892–1893, four Dundee whalers, the "Active," the "Balaena," the "Diana," and the "Polar Star," made a cruise to the Antarctic.† The ships made no geographical discovery, hunting for seals on the eastern coast of the western mainland, north of 65° south latitude. Mr. Murdoch, an artist, however, made some interesting notes about Antarctic

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*Kidder, J. H., M.D.: "Contributions to the Natural History of Kerguelen Island": *Bulletin of the United States National Museum*, Nos. 2 and 3. Government Printing Office, 1875 and 1876.

†"The *Scottish Geographical Magazine*," Vol. X, Edinburgh, 1894: pages 57–62, "The Story of the Antarctic," by William S. Bruce; pages 62–69, "The Late Expedition to the Antarctic," by Dr. C. W. Donald.

The Geographical Journal, Vol. VII, 1896: "Cruise of the 'Balaena' and the 'Active' in the Antarctic Seas, 1892–93;" pages 502–517, I. The "Balaena," by William S. Bruce; pages 625–643, II. The "Active," by Charles W. Donald, M.D.

Murdoch, W. G. Burn: "From Edinburgh to the Antarctic." Longmans, Green & Co., London and New York, 1894.

color, proving that the Antarctic is not as black as painted. For instance, he says:* "The reader must draw on his fancy for the coloring: the clouds soft warm grey, the crags of the berg to the right a purple lead color, the slope dull white; the berg to the left pale violet, with two or three upright clefts of deep blue, along the top an edge of pure white; between the bergs a third appears light emerald green. The floating ice in front, some parts creamy white, like broken marrons, others dead marble white, and two or three of vivid sky-blue, frosted with white; the sea an umber color, with lavender sheen."

Captain Larsen, a Norwegian sealer, made a cruise in 1892–1893 in the "Jason," on the eastern coast of the western mainland.† The following season, he made a long cruise‡ in the same vessel, landing at Cape Seymour, on November 18th. He says: "When we were a quarter of a Norwegian mile from shore, and stood about 300 feet above the sea, the petrified wood became more and more frequent, and we took several specimens, which looked as if they were of deciduous trees; the bark and branches, as also the year-rings, were seen in the logs, which lay slantingly in the soil. The wood seemed not to have been thrown out of water; on the contrary, it never could have been in water, because, in the first case, we found petrified worms, while there were none in the second. At other places we saw balls made of sand and cement upon pillars composed of the same constituent. We collected some fifty of them, and they had the appearance of having been made by man's hand." These discoveries are noteworthy, for they seem to be the only thing of the kind so far noticed in Antarctica.

From Cape Seymour, the "Jason" first sailed east, then returned and went south along the eastern coast of the

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*"From Edinburgh to the Antarctic," page 286.

† Murdoch, W. G. Burn.: "From Edinburgh to the Antarctic."

‡ "The Voyage of the 'Jason' to the Antarctic Regions:" *Geographical Journal*, London, 1894, Vol. IV, pages 333–344.

"*Norske G. S. Aarbog.*" 5. 1893–94, pages 115–131: "Nogle optegnelser af sael og hvalfanger 'Jasons' reise i Sydishavet 1893 og 1894, af Kapt. C. A. Larsen."

western mainland. Larsen christened this coast "King Oscar II. Land" and Foyns Land.* His down track was near 60° and 61° east longitude, and his most southern point, 68° 10′ south latitude, was reached on December 6, 1893.

Captain Evensen,† a Norwegian sealer, in November 1893, cruised in the "Hertha" along the coast of Graham Land. He passed Adelaide Island and the Biscoe Islands, which were almost free from ice, and sighted Alexander Land, which was surrounded by pack ice. He reached 69° 10′ south latitude, 76° 12′ west longitude; the absence of ice at this early period of the southern summer being the noteworthy feature of his voyage.

In 1894–1895, the Norwegian steam whaler "Antarctic" made a cruise to Antarctica.‡ It started from Melbourne on September 20, 1894. On November 6th, they saw such an immense ice island that it was mistaken for land and called Svend Foyn Island. After some cruising, the "Antarctic" reached the Balleny Islands from the north-east on December 14th; then, after much trouble with the ice, on January 16th, Cape Adare; on January 18th, Possession Island, on which several members of the expedition landed; and on January 22d the "Antarctic" was south-east of Coulman Island, in 74° south latitude. On January 23d, the expedition was back at Cape Adare, where a landing was effected, the first on Victoria Land. Some cryptogamic vegetation was found on Possession Island and also

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* It is probable that this coast was sighted by Morrell. See *ante*.

† This account is compiled from Dr. Fricker's "The Antarctic Regions," page 128, who quotes Dr. J. Petersen: "Die Reisen des 'Jason' und der 'Hertha' in das Antarktische Meer," 1893–94: Reprint from the "Mitteilungen der Geographischen Gesellschaft in Hamburg," 1895. I have not been able to find this latter paper.

‡ Bull, H. J.: "The cruise of the 'Antarctic' to the South Polar Regions." Edward Arnold, London and New York, 1896.

Borchgrevink, C. Egeberg: "The 'Antarctic's' Voyage to the Antarctic:" *Geographical Journal*, London, 1895, Vol. V, pages 583–589.

Kristensen, Captain Leonard: "Journal of the Right-Whaling Cruise of the Norwegian Steamship 'Antarctic', in Southern Seas: *Transactions of the Royal Geographical Society of Australasia*, Victorian Branch, Vol. XII-XIII, 1896, pages 73–100.

at Cape Adare, and a small number of right whales and many blue whales were seen during the cruise.

Lieutenant Adrien de Gerlache, of the Belgian Navy, in 1898–1899, led an important expedition to Antarctica.* The "Belgica" left Staaten Island on January 13, 1898, sighted the South Shetlands a week later, then crossed Bransfield Strait, and on the afternoon of January 23d was off the coast of Gerritz Archipelago. Here the expedition entered the supposed Hughes Bay, which proved to be the mouth of a new strait, which was called Belgica Strait, and which in size compares with the Strait of "Magalhaens." On the east is a land which was named "Terre de Danco," after a Belgian officer of the expedition, who died on June 5, 1898. On the west is an archipelago, and the action of the Belgians does them credit, for recognizing how much honor is due to Palmer as a discoverer in this portion of the Antarctic, they christened this archipelago, "Archipel de Palmer," and so marked it on their charts.†

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* Cook, Frederick A., M.D.: "Through the First Antarctic Night." New York, Doubleday & McClure Co., 1900. Appendix No. VI of this book: "The possibilities of Antarctic Exploration," touches on the possible political rights of nations in Antarctica; it is undoubtedly the most accurate essay so far written about the Antarctic.

"Société Royale Belge de Géographie:" Bulletin; Vingt-quatrième Année, 1900, No. 1, pages 230. This contains:—

I. "Expédition antarctique belge."

II. G. Lecointe: "Aperçu des travaux scientifiques de l'Expédition Belge."

III. G. Lecointe: "L'hydrographie dans le détroit de 'la Belgica' et les observations astronomiques et magnétique dans la zone australe."

IV. H. Arctowski: "Géographie physique de la région visitée par l'expédition de 'la Belgica.'"

V. E. G. Racovitza: "La vie des animaux et des plantes dans l'Antarctique."

Bulletin de la Société Royal de Géographie d'Anvers, 1900, Tome XXIV, pages 25–51: "Expédition Antarctique Belge," par M. Georges Lecointe.

The Geographical Journal, Vol. XVII, 1901, pages 150–180: "Exploration of Antarctic Lands," by Henrik Arctowski.

† Lieutenant de Gerlache in his recently published papers in the "Société Royale Belge de Géographie," Bulletin, Vingt-quatrième Année, 1900: "Notes sur les expédition * * * aux régions circumpolaires voisines du méridien du Cap Horn," and "Relation sommaire du voyage de la Belgica," pages 365–531, has applied the name of "Gerlache Strait" to "Bel-

Over a hundred islands were discovered in Gerlache Strait, on both sides of which are many peaks, and great ice and snow masses. Many names were bestowed, among which may be mentioned Liège, Gand, Braband, Anvers and Wiencke Islands. The officers made several landings, and many discoveries, and instead of raising flags to take possession of newly-discovered lands, they decided that the first chart of a new country was as good a deed to the title of land, as the formality of pinning a bit of bunting to a temporary post and drinking to the health of a royal ruler. Mr. Arctowski found an insect here, which is probably the first one reported from Antarctica; it was almost microscopic in its dimensions. In about three weeks' time, the "Belgica" sailed without serious difficulty more than three hundred kilometers southwesterly, through Gerlache Strait. To the east the shore line of Danco Land was unbroken; there were many deep indentations, but no passage into the Atlantic. A continuous wall of ice, from fifteen to thirty meters high, fronted the coast everywhere. This land is from 600 to 1200 meters high, with mountains farther inland, perhaps 1800 meters in altitude. Every valley and every surface which was not perpendicular was buried under a sheet of ice. The "Belgica" was unable to follow the coast far enough south to determine whether Danco Land is continuous with Graham Land. On February 13th the "Belgica" was fairly through Gerlache Strait, and for the next few days sailed southwest through an icy ocean, obtaining glimpses of the distant coast of Graham Land. On February 16, 1898, the expedition passed the Alexander Land or Islands, which proved the last land they saw.

De Gerlache now tried to force his way south and west, and succeeded to a certain extent in doing so; but as a result the ship was frozen in and consequently wintered in the pack, from which it was finally liberated in March, 1899.

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gica Strait," and "Gerritz Archipelago," to the islands west of the strait. Both these changes, its seems to me, should be accepted. He also charts the northern coast of the main land as Palmer Land or Trinity Land—and, in my opinion, the first name is the correct one.

The men suffered severely from the absence of sunlight and the lack of fresh food. They were at last driven to eat penguins, whose flesh Dr. Cook describes as appearing to be made up of an equal quantity of mammal, fish and fowl, and as tasting like a piece of beef, an odoriferous codfish, and a canvas-back duck, roasted in a pot, with blood and cod-liver oil for sauce. The furthest southern point, 71° 36′ south latitude, 87° 33′ west longitude, was reached on May 31, 1898. Nething was seen of Peter I Island, and the course of the ship proved that there was no land near Captain Cook's nor Lieutenant Walker's furthest points.

Perhaps the most important discovery of the Belgian expedition is that of a continental tableland or plateau, situated between 75° and 103° west longitude and 70° to 71° 36′ south latitude. The depth of this continental plateau, from 200 to 500 meters, with an abrupt fall to 1500 meters towards the north, shows that this region has also undergone the depressive movement, which was noticed in the lands of Gerlache Strait. The continental plateau rises gently towards the south, and lowers in its eastern portion towards the north to connect with the continental plateau of Graham and Alexander Lands. It must connect in like manner 50° farther towards the west with the continental plateau discovered by Ross east of Victoria Land. This would show that there is a continuous or uninterrupted continental mass from 50° west longitude, to 63° east longitude, and the discovery made by the "Belgica" gives, therefore, a serious support to the hypothesis of an antarctic continent. The terreous nature of the sediments of the continental plateau and neighboring regions, which contain, besides a grayish slime, a strong proportion of sand, gravel and a number of pebbles of rounded form, are in decided support of this hypothesis. The meteorological observations also show that there must be a great antarctic ice-cap. The minimum temperature,—43°, was observed in September; the maximum, + 2°, in February. The month of July, with an average of — 22·5°, was the coldest of the year; the month of February, with an average of — 1°, was the warmest. The mean temperature of the year was—9·6°,

an extraordinarily low figure for that latitude. This low temperature can only be explained by the absence of land towards the north, and the presence of an antarctic continent entirely covered with ice to the south. The hypothesis is based upon a fact which was observed by the expedition. Every time the wind blew from the north the temperature rose, even in mid-winter, to 0°, but did not ascend higher. As soon as the wind shifted and blew from the south, the thermometer descended abruptly, even in the middle of summer, to a low temperature.

The "Belgica" expedition brought back perhaps more scientific data about the Antarctic than any other expedition so far, and the captain and members deserve the highest praise for their labors.

Professor Chun, of Leipzig, in 1898–1899, led the German deep-sea expedition in the "Valdivia.* Starting from Cape Town on November 13, 1898, on November 25th they sighted Bouvet Island, which was located—finally, let us hope—at 54° 26′ south latitude, 3° 24′ east longitude. Lindsay and Liverpool Islands are probably identical with Bouvet Island, and Thompson Island is perhaps non-existent. Bouvet Island is volcanic, covered with one vast glacier, and no trees were seen through the telescope.

The "Valdivia" then proceeded east and south. The edge of the pack was traced from 8° east longitude to 58° east longitude; the most southerly point reached was 64° 15′ south latitude, 54° 20′ east longitude, when the "Valdivia" was one hundred and two nautical miles from Enderby Land. At this point the enormous icebergs and the strong ice blink to the south proved proximity to land, and it is questionable whether some of the high ice peaks in the far distance did not belong to it. The "Valdivia" came north to Kerguelen Island at the end of December and then left the Antarctic seas.

The scientific results of the voyage are important. The icebergs seen between Bouvet Island and 40° east longitude

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* *The Geographical Journal*, London, Vol. XII, 1898, pages 494–496; Vol. XIII, 1899, pages 297,298, 640–650; Vol. XV, 1900, pages 518–528.

were weather-beaten and carved into grotesque forms; suggesting that they had already made a long voyage and, therefore, that no land exists between 0° and 40° east longitude, except perhaps in high polar latitudes. Between 40° and 62° east longitude, where the icebergs increased, tabular icebergs were found, and the farther east the ship went, the more such tabular bergs did it find. Some of them were to all appearances just broken off the land and showed no clefts. Some rocks, which had dropped from the melting icebergs, were collected in trawls: gneiss, granite, schist and red sandstone, but no volcanic rocks, showing that Enderby Land is not of volcanic origin. This is surprising on account of the soundings made by the "Valdivia." All those between Bouvet Island and Enderby Land were generally over 2,000 fathoms, and the deepest was 3,134 fathoms. This shows that at least between 0° and 50° east longitude, and south of 55° south latitude, there is a fairly regular and deep depression, with no suggestion of a plateau.

Mr. C. E. Borchgrevink led an expedition to Antarctica in 1898-1900.* He struck the ice in 51° 56′ south latitude, 153° 53′ east longitude, then finding the ice conditions unfavorable—which he thinks they always are in this locality—he went east and sighted the Balleny Islands on January 14, 1899. He had trouble with the ice, and was forced northward and eastward. Finally the "Southern Cross" ran into open water and reached Cape Adare on February 17th.

At Cape Adare, Mr. Borchgrevink and the members of his expedition landed and the "Southern Cross" returned north. The expedition spent the winter at Cape Adare in Camp Ridley, making short expeditions in the neighborhood and also scientific observations. Most of the rocks in the neighborhood are of volcanic origin, and represent basaltic lava flows which have taken place during late geological epochs. Six different kinds of lichen were found,

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* Borchgrevink, C. E.: "The 'Southern Cross' expedition to the Antarctic: *The Geographical Journal*, London, 1900, Vol. XVI, pages 381–414.

including the ordinary reindeer moss; specimens were obtained as high as 900 meters. In the lichen three distinct types of insect were found: apparently the second discovery of the kind in Antarctica. In Robertson Bay there is also an abundance of fish, and about five different kinds were discovered. August was the coldest month, the mean temperature being —25° 2 C. Many tremendous gales were experienced, the wind sometimes exceeding 90 miles an hour and proving a serious check to sledge expeditions: these gales always came from the same direction, east-southeast.

The "Southern Cross" returned to Cape Adare on January 28, 1900. The expedition then went south, along the coast of Victoria Land. They made a landing in Southern Cross Firth, at the foot of Mount Melbourne, and another at the foot of Mount Terror. From Mount Erebus a smoke cloud was occasionally shot up into the air. The "Southern Cross" then followed the ice barrier eastward until, on February 17th, it reached 78° 34′ south latitude, 164° 10′ west longitude, where a break was discovered in the barrier. Mr. Borchgrevink landed with Lieutenant Colbeck and the Finn Savio, and proceeded southward, reaching 78° 50′ south latitude, the furthest south yet reached. The "Southern Cross" then returned north.*

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*Among valuable papers about the Antarctic may be mentioned the following:

Reiter, Dr. Hans: "Die Südpolarfrage, II. Antarktis, der Sechste Kontinent;" *Zeitschrift für wissenschaftliche Geographie*, Weimar, 1887.

Bartholomew, J. G., F. R. S. E., Hon. Sec. R. S. G. S.: "Antarctic Bibliography;" *Scottish Geographical Magazine*, Vol. XIV, Edinburgh, 1898, pages 563–570.

A bibliography of the papers of the veteran German scientist, Dr. George Neumayer, will be found in Sir John Murray's "The Renewal of Antarctic Exploration," *Geographical Journal*, Vol. III, 1894, pages 40, 41.

ELECTRICAL SECTION.

Stated Meeting, held December 20, 1900.

ELECTROCHEMICAL ACTION.

BY C. J. REED, Member of the Institute.

(*Concluded from p. 413.*)

Nascent State.—One of the most popular fallacies in regard to electrochemical action is the belief that the formation of hydrogen gas at the cathode is a cause of polarization, and that the function of a depolarizer or cathode reagent is to "absorb hydrogen." Hydrogen is sometimes liberated at the cathode as a result of polarization (exhaustion of the proper reagent), but is never the cause of it. If hydrogen is allowed to form, it may act as an obstruction, causing increased resistance, which is very different from polarization.

This fallacy in regard to hydrogen gas seems to be based on the equally absurd belief that water is the only substance capable of undergoing electrochemical decomposition, and that all reduction products except hydrogen, which are formed in an electrochemical cell, are produced by secondary reactions as a result of the reducing action of hydrogen. According to that belief, hydrogen always reduces the cathode reagent or depolarizer, and when the depolarizer is exhausted, the hydrogen appears and "polarizes" the cell. Why hydrogen should have been assumed to be the only substance capable of electrochemical reduction is not apparent, unless it is because water happens to be the cheapest known solvent and happens to be almost universally present and accessible to the circuit in electrolytic solutions.

If we compare the different substances in the table of electrogenic powers, it is difficult to find anything that distinguishes water as the only substance capable of electro-

chemical decomposition. On the contrary, the law of maximum electrogenesis applies to water as well as to any other substance, and any compound, whose electrogenic power is less than 1·48 volts, such as cupric chloride or argentic sulphate, will be decomposed before water is decomposed and before any hydrogen is liberated. Furthermore, it follows from the principle of the conservation of energy, that any substance which has a greater energy of combination than that of hydrogen cannot be decomposed by hydrogen, except by the absorption of external energy. Therefore, hydrogen cannot cause the secondary reduction of any electrolytic conductor in any case of electrochemical reaction, though it may reduce non-conducting substances incidentally present, whose formation heats are less than that of the hydrogen compound. Such secondary reactions, however, are always thermochemical and independent of the electrochemical reaction.

If hydrogen were capable of displacing from a compound an element more highly electrogenic than itself, we should have in that process an inexhaustible source of energy. For example, the combination energy of zinc with oxygen is greater than that of hydrogen with oxygen. Hence, if hydrogen can displace zinc from zinc oxide without absorbing energy, the problem of creating energy is solved without the aid of the philosopher's stone.

But the advocates of the secondary reduction theory say this hydrogen is in the "*nascent state*," and that in this state it has a greater power of reduction than in the ordinary state, and that it can, therefore, reduce zinc, though the combining energy of the zinc is greater than that of the hydrogen. This is assuming, without the slightest evidence, firstly, that the hydrogen performs an impossibility, and secondly, to explain this impossibility, that the hydrogen is in an impossible state.

Let us consider for a moment what this so-called "nascent state" must be. It is defined merely as "the state or condition of an element immediately after it is set free." If it is possible to conceive an atom possessing greater energy in this state than in the immediately preceding or

the immediately succeeding state, without either receiving or evolving energy in passing from one of these states to the other, we can understand the "nascent state."

Hyperergia.—There is another phenomenon resembling polarization, though quite distinct from it, which deserves mention. In the copper-copper-sulphate cell, shown in *Fig. 4*, the continuous passage of a current from an external source in the direction of the arrow will cause an exhaustion of the copper sulphate at the cathode, C, by the removal of copper from solution. But at the anode, C', nothing is removed from the electrolyte, and there will be no exhaustion of the copper sulphate, but an increase, due to the formation of additional copper sulphate at that point. The phenomenon of polarization or exhaustion cannot occur, therefore, at the anode, until the copper is exhausted, and there can be no diminution of electromotive force at this electrode through an indefinite continuation of the current. If, however, the strength of the current should be increased until it reaches an intensity corresponding to the total number of molecules of copper sulphate in contact with the electrode at any one time, it is evident that the copper sulphate cannot then transmit a still greater current. If the current be increased beyond this strength, the excess of current must find some other electrolytic path. It must decompose the water present and produce copper oxide or free oxygen. The production of copper oxide is less electrogenic than the production of copper sulphate, and the liberation of free oxygen is electrothanic. An electromotive force is absorbed here and the cell becomes electrothanic. The change in electromotive force caused by this excessive current is similar to the change produced by exhaustion or polarization, except that it is due to a different cause and disappears as soon as the current strength is reduced below a certain limit. There is no specific name for this condition of the cell, but it might with propriety be called *hyperergia*, from ὑπέρ and ἔργον, signifying an excessively worked condition at either electrode.

There is another cause of variation in the electromotive force of an active electrochemical system, which must not

be mistaken for polarization. This is thermoelectric action, which depends upon temperature relations and current strength, but is not caused or increased by exhaustion of the reagents.

Electrolytic Separations.—We have already referred to the fact that the electrolytic separation of metals is governed by and dependent upon the law of maximum electrogenesis. Its application is very simple and we shall consider briefly two different cases. In the first case, let us suppose a separation is to be made of a mixture of several metallic salts in solution, such as the bromides of copper, nickel, cadmium, and zinc. In order to separate these metals from solution, electrodes of platinum may be used, which introduce no impurities.

When an electric current is passed through the mixture of metallic bromides between platinum electrodes from a governable external source, bromine will be separated at the anode and the metals at the cathode.

From the table of electrogenic powers we find that the separation of cupric bromide requires 0·86 volt; nickel bromide, 1·56 volts; cadmium bromide, 1·64 volts, and zinc bromide, 1·97 volts.

It is evident that as long as the electromotive force of the cell remains above 0·86 volt and below 1·56 volts, copper alone will be deposited at the cathode, and bromine at the anode. As the density of the copper bromide in the solution diminishes, either the current must diminish or the electromotive force must increase. In order to prevent the deposition of any of the other metals present, the electromotive force must be kept below 1·56 volts, and, as the exhaustion of the copper proceeds, the current must continue to diminish until, with the last traces of copper, it becomes infinitesimal. The time required for the complete separation would be infinite. In other words, it is impossible to completely remove the copper under these conditions without removing some of the nickel, though it may be reduced to a high degree of exhaustion after a long time.

When this exhaustion has been reached, the electromotive force is increased above 1·56 volts, but not above 1·64

volts. The strong current now flowing rapidly removes most of the nickel together with the residual copper. When the exhaustion of the nickel has proceeded to a sufficient degree, the electromotive force is increased above 1·64, but kept below 1·97 volts, until the cadmium has been removed. Finally, the electromotive force is increased above 1·97 volts and the zinc removed. The current may now be maintained at any strength and all traces of the several metals entirely removed. But copper, the first metal removed, will be the only one free from other metals. Each metal after the first will be contaminated with a small portion of the preceding metal and probably with more than one.

In practice there are always conditions present that greatly modify these results. For example, the bromides above named could not be mixed together in an electrolyte without either fusion or the presence of a solvent, such as hydrogen bromide or water, which would undergo decomposition and liberate hydrogen when the proper electromotive force is reached. If the fused bromides were used, the electromotive forces would have to be determined for the high temperatures required for fusion. If the solutions have a high resistance, the prescribed electromotive forces may be unable to send a current of sufficient density to prevent recombination by thermochemical action of the deposited metal and the bromine, unless the products are kept separated by a porous partition.

Very different results are obtainable, however, in the case of a mixture of metals instead of a mixture of solutions of metallic salts. In this case one metal can be separated in a state of purity at the cathode, while those which are electro-positive to it (more electrogenic) are left in solution, and those which are electro-negative to it (less electrogenic) are left on the anode. Let us suppose, for example, that metallic copper is to be freed from silver, gold, iron and zinc.

For the electrolyte we use in this case an aqueous solution containing a pure copper salt, such as the sulphate. This solution is not deprived of any of its original quantity

of copper during the process, but is used only as a medium, through which copper is transferred from the impure anode, comprising the mixture of metals, to the cathode, which generally consists of a sheet of pure copper. A strong current of constant strength may here be advantageously employed. The smallest electromotive force is sufficient to send a current through this agenic cell, depositing copper at the cathode and dissolving it from the anode.

From the table of electrogenic powers we find that the electrochemical electromotive force of copper sulphate is 1·21 volts and that of silver sulphate, 0·47 volt, while that of gold sulphate, if it forms a sulphate under the conditions, is much less and probably negative. Hence, as there is neither gold nor silver in the solution, the silver cannot be dissolved without an electromotive force exceeding the difference between 1·21 and 0·47 volts, or 0·74 volt, and the gold cannot be dissolved without a still greater electromotive force. But the copper, zinc and iron all freely dissolve by the electrochemical deposition of the copper at the cathode with any electromotive force greater than zero. The electrogenic power of ferrous sulphate is 2·02 volts, and that of the zinc sulphate 2·30 volts. Hence, iron will not be deposited if the electromotive force between the terminals is less than the difference between 2·02 and 1·21, or 0·81 volt, and zinc will not be deposited if the electromotive force is less than 2·30—1·21, or 1·09 volts.

The law of maximum electrogenesis acts at both terminals of the electrolyte, preventing the silver and gold from dissolving at the anode and preventing the deposition of the iron and zinc at the cathode. Assuming the figures in the table to be accurate, we may feel reasonably certain that, in the refining of copper by this process, the copper product will be free from silver and gold, if the electromotive force is kept below 0·74 volt per cell; that it will be free from zinc and iron, but may contain silver, if the electromotive force is between 0·74 and 0·81 volt; that it will be free from zinc, but may contain silver and iron, if the electromotive force is between 0·81 and 1·09 volts. We may also have the liberation of hydrogen if the electromo-

tive force exceeds 1·48 — 1·21, or 0·27 volt. But so long as the quantity of copper sulphate at the cathode is in excess of the amount necessary to transmit the total current, there will be no deposition of either iron, zinc, hydrogen, or any substance more highly electrothanic than copper, even though the electromotive force may be greatly in excess of that required for such separations, since, by the law of maximum electrogenesis, the reaction absorbing the least electrical energy must be exhausted first. If, for example, the electrolyte be put into an elongated form, so that its total resistance is 100 ohms and an electromotive force of 10 volts be employed, the total current through the cell cannot exceed $\frac{1}{10}$ ampère. If at the same time the solution of copper sulphate at the cathode is very strong and the area of the cathode is not less than 5 or 6 square inches, there could be no deposition of hydrogen, iron or zinc, although the electromotive force is nearly ten times that required to deposit any of these substances under other conditions. Under the conditions named, the high electromotive force applied to the cell would not be absorbed in the electrochemical reaction, that is, in doing the work of chemical separation, but in generating heat in overcoming the resistance of the electrolyte. Under such conditions the electrolyte surrounding the cathode must be kept in motion by other means than diffusion, or the exhaustion of the copper sulphate, even to a slight distance, will reduce the current, causing part of the high electromotive force to be applied to the electrochemical work at the cathode, instead of to the resistance. When this occurs, the hydrogen, iron, and zinc will be deposited. This is always avoided in the practical refining of copper by using a cell of such a form that its resistance is small, in order that the electromotive force may always be kept below the limit required to deposit any objectionable metal.

Changes in Concentration.—It has been stated above that, in the electrolysis of copper sulphate between copper electrodes, the electrochemical action causes the solution to become weaker in copper sulphate at the cathode and stronger at the anode. This and all similar changes in con-

centration, caused by electrochemical action, may be explained very satisfactorily without the necessity of much theory. In *Fig. 8* let *C* and *C'* represent two copper electrodes, the small circles, *c*, representing atoms of copper. Let us suppose that these eletrodes are connected by the solution containing molecules of copper sulphate. Let each molecule of copper sulphate be represented by two circles connected by a line, the circle marked *c* representing an atom of copper, and the circle marked *s* representing the

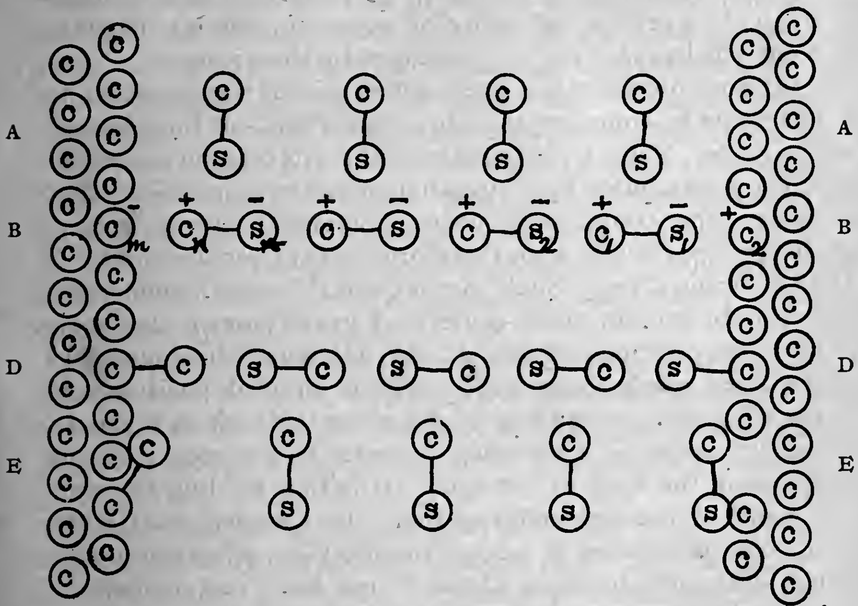

FIG. 8.

SO_4 group of atoms. The line connecting these two components of the molecule in the diagram represents the chemical affinity or attraction that holds the molecule together.

Confining our attention for the present to the upper part of the figure, marked *AA*, we have between the electrodes four molecules of copper sulphate uniformly distributed. It is not necessary to assume that these molecules have or have not any particular arrangement or positions.

Nor is it necessary for us to assume that they have or have not any motion, either of rotation or translation. It is only necessary, for our purpose, to suppose that these molecules are free to move or rotate under the influence of impressed forces. We are at liberty, however, to assume, merely for convenience of illustration, that they are uniformly distributed and arranged in a regular order, as shown at *AA*. Let us now suppose that the electrodes, *C* and *C'*, are connected to a governable source of electromotive force and become permanently charged, *C'* positively and *C* negatively, to a certain difference of potential, tending to cause a current in the direction indicated by the arrow.

It does not require a great effort of the imagination to enable us to conceive that the first effect of the charged electrodes, *C* and *C'*, is to polarize the intervening molecules of copper sulphate by giving them a static, inductive electric charge, the copper end of each molecule being always charged positively and, therefore, always repelled from *C'* and attracted to *C*. Such charges would cause the molecules to rotate around their centers of gravity until they come into the positions shown at *BB*, whatever their previous positions might have been. These induced positive and negative charges, tending to move the two ends of the molecule in opposite directions, necessarily produce a stress opposing the force or chemical attraction holding the components of the molecule together. It is evident that when the charge reaches a certain intensity, or, when the potential difference between *C* and *C'* reaches a certain definite value, the repulsion between the oppositely charged components of the molecule will equal the affinity holding them together.

When this condition is produced, it is evident that any positively charged copper atom, c_1, is attracted equally by each of the two adjacent negatively charged atomic groups, s_1 and s_2, and that the negatively charged atomic group, s_1, is equally attracted by each of the two adjacent positively charged copper atoms, c_1 and c_2, the atom, c_2, being a part of the positively charged electrode, *C'*. The same is true of the entire series or chain of molecules reaching from *C'* to *C*, the

terminal positively charged copper atom, c_n, of the electrolyte being attracted to the adjacent negatively charged copper atom, c_m, of the electrode *C*. Any infinitesimal increase in the potential difference will now cause the charged component, c_1, to abandon its partner, s_1, and unite with the adjacent and more strongly attracting s_2, the atomic group, s_1, uniting simultaneously with c_2 of the anode, and so on throughout the series.

The succeeding state of the system is represented at *DD*, the electric charges having mutually neutralized one another, leaving the same number of molecules of copper sulphate as in the initial state. But the centers of gravity of these new molecules are all nearer to the electrode, *C′*, by half of the mean distance between two adjacent molecules. This is shown more plainly at *EE*, which represents the molecules as having rotated about their centers of gravity until they have the same relative positions as at *AA*. The newly formed copper molecule at the cathode, *C*, being firmly attached to the solid electrode, can only rotate until obstructed by that body.

After this series of changes we see that the electrode, *C*, has one more atom of copper than in the initial state, that the electrode, *C′*, has one atom less, that the number of molecules of copper sulphate is the same, but that their centers of gravity are nearer to *C′*.

These changes in concentration at the electrodes, according to the theory advanced above, are caused by the chemical changes in the electrolyte at the electrodes, that is, the introduction of copper into the electrolyte at *C′*, and its elimination from the electrolyte at *C*, in conjunction with the interchange of molecular components and the rotation of the molecules about their centers of gravity.

In regard to the energy and the electromotive force concerned in these changes, it is evident that the charging of the entire series of molecules inductively to the potential of the electrodes will require the same electromotive force, whether there are four molecules in the series or only one. We may, therefore, consider this series as a single molecule, acted upon inductively by the two electrodes, as shown in *Fig. 9*.

Whatever electrical energy may be expended in producing this inductive charge in the molecule, is evidently expended in overcoming the chemical affinity of its components. This affinity or attraction can be overcome only by restoring to the components of the molecule the chemical potential energy lost by them in combining. The attraction of the atomic group, s_1, for the copper atom, c_1, *Fig. 9*, decreases only as its attraction for c_2 increases. As s_1 acquires chemical potential energy with reference to c_1, it loses chemical potential energy with reference to c_2. That is, as s_1 passes from the influence of c_1 to that of c_2, it undergoes no actual change in its total chemical potential energy, because c_1 and c_2 are similar atoms. In other words, the

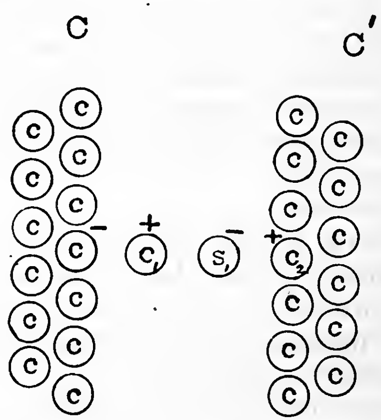

FIG. 9.

chemical affinity of s_1 is merely transferred gradually from one atom of copper to another. No energy is required for such a change and, therefore, no external electromotive force will be absorbed or evolved in this transfer of chemical affinity. This is equivalent to saying that the chemical energy generated by separating c_n (*Fig. 8*) from s_n at the cathode is equal to that which disappears by simultaneously combining s_1 with c_2 at the anode. The only external energy required is that necessary to rotate the polarized molecules about their centers of gravity and bring them into the position shown at *BB* without causing any translation. The frictional resistance of the medium to this rota-

tion would require a conversion of electrical energy into heat, that is, an electromotive force would be absorbed in overcoming the resistance of the electrolyte while the rotation continues. But the absorbed energy would be only proportional to the quantity of heat generated per unit of time, that is, to the square of the velocity of rotation. The velocity of this rotation would be proportional to the rate of electrochemical action, which, by Faraday's law, is proportional to the quantity of electric charge transported per unit of time, that is to the strength of the current. The electrical energy converted into heat by this molecular rotation must, therefore, in an electrochemical reaction, be proportional to the square of the current, corresponding to Joule's law.

It is evidently not necessary to assume that there is any transportation of matter by the electric current other than that which results from the molecular rotation described above. And whatever translation results from such rotation cannot be considered as an independent migration of dissociated ions moving with different velocities, but must be considered to result from equal velocities of rotation of the two kinds of united ions or molecular components. What is really transported or transferred from molecule to molecule directly by the current is the chemical affinity.

The chemical energy evolved or absorbed by an active electrochemical system will evidently be zero only when the chemical change at one terminal is the reversal of the chemical change at the other terminal. In all other cases there will be an evolution or absorption of electrical energy, due to the chemical changes, and a corresponding difference of potential will be developed between the electrodes. The value of this will be the sum of the electrogenic powers of the chemical changes at both electrodes, as has already been described with reference to the Daniell cell.

Faraday's Law of Electrochemical Equivalents.—The capacity of a monovalent atom or group of atoms for an electric charge sufficient to transfer its affinities is always the same, whatever may be the substance. The capacity of a divalent atom or group of atoms is always double that of a

monovalent atom, and, in general, the capacity of any atom or group of atoms is 96,540 coulombs multiplied by the change in valence suffered by the atom or group in the electrochemical action.

Stated in another form, this is Faraday's law of electrochemical equivalents.

Kohlrausch's Law of Electrolytic Conductivity.—The resistances of solutions of an electrolyte of various strengths have been very carefully determined by Kohlrausch in his classical researches. The results of his experiments on conductivity may be stated in the form of a law as follows:

The specific conductivity of an electrolyte, dissolved in a non-conducting medium, is inversely proportional to the mean distance between the molecules of the dissolved electrolyte.

This is not the form in which the results of Kohlrausch are generally stated, but it is a true statement of the relation between the strength of a dissolved electrolyte and the specific resistance of the solution. It is also a statement of what would necessarily follow from the truth of the theory of electrochemical action set forth above.

This theory of electrochemical action has not, to my knowledge, been propounded heretofore in exactly this form, though it is substantially that proposed by Faraday in 1833, and it is offered only for what it may be worth, as it seems to account satisfactorily for all changes in both energy and matter, including changes in concentration, or the so-called "migration of ions." It is also consistent with other observed facts, both physical and chemical, particularly those relating to solutions and to changes of state, temperature, and pressure. To the recent theory of "electrolytic dissociation," on the other hand, there appear to me to be insurmountable difficulties. But this subject is too large for its discussion to be entered upon here.

NOTE.—The equation on page 391 of the May number should read

$$4{\cdot}40 - (-0{\cdot}08) = 4{\cdot}48 \text{ volts.}$$

Mining and Metallurgical Section.

Stated Meeting, held Wednesday, February 13, 1901.

UTILIZATION OF THE WASTES FROM THE USE OF WHITE METALS.

By Joseph Richards, Member of the Institute.
(Being the Address of the Retiring President.)

(*Concluded from vol. cli, p. 455.*)

In the paper read before the section last month I treated the subject of tin clippings and zinc wastes. To-night I will speak of other wastes from the white metals, such as zinky-lead, tin-lead, antimony and its alloys, babbitt, type-metal, britannia and pewter. Also the oxides and skimmings that are taken from these metals, oxides and sulphate of lead, lead chamber wastes, "sweeps" from metallic paint works, skimmings from the pots in tin and terne-plate industries, or any other residues containing sufficient metal to pay for their reduction or refining.

Zinky-lead.—One of the first things we found it necessary to treat was zinky-lead. As I stated last month, Western spelter carries about 1½ per cent. of lead. In galvanizing, the spelter is added as often as necessary to keep up the supply in the bath. An ordinary pot will use 3 or 4 tons per week. A part of this lead sinks to the bottom of the bath, and when the bath is bailed out we obtain from 1 to 3 tons of impure lead. If this is melted in a large cast-iron pot, the molten zinc floats to the top and the lead settles to the bottom. The pot is heated just hot enough to melt the lead, and the particles of zinc, in a pasty state, float on top. A large ring about 2 feet in diameter and 6 inches deep is placed in the center of the pot. Then a ladle is taken, and by continued skimming the zinc is removed from the interior of this ring until we have a clean lead surface. The lead is then bailed out and cast into moulds or ingots.

The heat of the pot is then raised and the zinc is melted. The product is still impure, as zinc will carry about 2 per cent. lead and the lead about 3 per cent. zinc that will not settle out by this process. There is, however, considerable demand for lead for ballast, weights, counterbalances for wheels and other purposes, so that it is seldom necessary to refine the lead any closer. If we wish to do so, we have only to pass it through our refining furnace, in which the temperature may promptly be raised so high that all the zinc is volatilized and the lead becomes pure. The zinc is passed through our zinc furnace to refine in the same manner as the dross is treated.

Britannia and Pewter.—The next to command my attention was old britannia and pewter. These metals are composed of tin, lead, antimony and a little copper, varying in their composition from the English hall-marked pewter containing 92 per cent. tin, 6 per cent. antimony and 2 per cent. copper, to britannia which contains 30 per cent. tin, 6 to 10 per cent. antimony and 40 to 60 per cent. lead.

Nearly all of this metal is plated with silver, which it is necessary first to remove. We employed for this purpose the method commonly called "stripping," by plunging the articles in nitric acid contained in a porcelain-lined pot and permitting them to remain in the acid until all the silver was dissolved. The articles were well washed and dried, and then broken up and melted. The metal was used in making type, stereotype and babbitt metal. Its composition was changed, adding the desired quantity of tin, lead, antimony or copper, according to what mixture we desired to make.

The "stripping" pot was kept covered to keep the acid from evaporating, and from time to time we cleaned the old plated ware until the acid was nearly neutralized. Then common salt was added, which precipitated all the silver as chloride, which was fused with flux in a plumbago crucible to reduce it to metallic silver.

I commenced about this time to make solder for the Standard Oil Company and had considerable quantities of skimmings from the solder pots. Failing to find a purchaser for these skimmings, I proceeded to utilize them in the fol-

lowing manner: I ground and then washed them on a very fine sieve, and by this means recovered directly 50 per cent. of clean shot metal, and the oxide that was left was reduced in a crucible with carbon, yielding from 60 to 70 per cent. metal.

From that time forth I saved all my oxides for future treatment. For this purpose I built four air or pot furnaces like those used in brass melting. Their capacity was such that I soon used up all the oxides in stock, and then I systematically visited all the metal works in this and neighboring cities and found nearly all of them sieving out the shot metal to melt in their pots. The dirt (as they called it) was thrown away. I persuaded them to save the dirt for me, and while the first lot came cheaply, it soon had a market value.

We reduced the oxides in crucibles and found that the resultant metal had a very complex composition. Although it was supposed to be tin and lead only, we found mixed with it all kinds of impurities, such as iron, zinc, copper, arsenic, antimony, nickel and other metals. This necessitated the refining of the crude reduced alloys so as to get them in a marketable shape. If lead and tin predominated, 1 per cent. of iron, zinc, copper or antimony rendered it unfit for solder, the natural product of tin and lead.

These crude metals were cleaned by using sulphate of zinc to remove arsenic, sulphur to remove the antimony and superheated steam or chlorine gas to remove the iron. Salt, rosin, sal-ammoniac and other fluxes were used, leaving, after treatment, a pure alloy of tin and lead for solder making.

The crucible practice being found slow and unsatisfactory, I built one of the old-fashioned furnaces such as the Chinese use in reducing tin ore, of which we soon had three in operation.

I found that they could be run continuously and that I could add to the charge the necessary flux to take the iron and copper down in the slag. The zinc and arsenic were partially volatilized, and, if desired, also a good part of the antimony. Business grew and this method was found too

slow, so I built a water-jacketed furnace that worked much faster, the one furnace having a capacity ten times greater than that of the other three combined. Unfortunately, we did not do much work with this furnace, because of the exorbitant charge of the city water bureau ($850 a year) for the water necessary to keep it cool.

I then built a furnace of peculiar design, perfectly adapted for this use, a furnace that gave me a perfect reducing flame, absolutely under control and saving 70 per cent. in fuel.

In this furnace it was easy to treat 3,000 to 4,000 pounds at a charge. I could slag out copper and iron, volatilize other impurities and obtain a much better product. The furnace was fitted with a large condenser to cool the vapors and recover any volatile matter that might escape and annoy the neighbors.

In working this furnace the oxides are mixed according to their action in the furnace. The action of lead oxide, or litharge, on the firebrick destroys the lining of a furnace very quickly. I have known it to eat up to a thin wedge shape a 9-inch silicon firebrick in forty-eight hours. This action can be neutralized by using tin oxide and other oxides. No flux, or very little, is used and economic results are obtained.

The crude metal reduced from the oxides is liquated on an inclined hearth at a low heat, leaving copper, antimony and iron as a residue.

After liquation the metal is melted in a 10-ton pot furnace to produce a uniform mixture. When tested at this point it usually runs 25 per cent. tin, 70 per cent. lead, 1 to 2 per cent. antimony and a little iron and copper. This metal is treated in a manner similar to the zinc in the zinc furnace, using the desired reagents to remove antimony, iron and copper. The treatment is continued until the metal is pure.

Type metal oxides reduced in this manner make better solder than that made from metals found in the market.

The copper and antimony concentrates are used for babbitt metal.

Alloys of copper in excess can be used for brass.

Alloys of tin, lead, antimony can be used for type, stereotype and electrotype, or linotype metals. Lead and tin alloys are used for solder.

I will mention, in conclusion, the valuable aid that I have received in this work from the testing machine which I have devised and which I show you. It is a difficult and tedious task to determine the proportions of tin and lead in a tin and lead mixture, but with the help of this machine the result can be obtained in five minutes. These machines are now in use in all the large smelting works in this country and in Europe.

PHYSICIAL SECTION.

Stated Meeting, held March 23, 1901.

THERMOMETER GLASS AT HIGHER TEMPERATURES.

WM. McCLELLAN, B.S.

Morgan Laboratory of Physics, University of Pennsylvania.

It is well known that an ordinary mercury-in-glass thermometer cannot be used for temperatures much over 300°, for the reason that mercury, under atmospheric pressure, boils at 357°. In addition to this, the fact that some of our hardest glass, while it does not actually become plastic, reaches a critical state at about 410°, sets a second limit. The increase in plasticity is, of course, so very slow as we pass above this point, that glass thermometers are used at considerably higher temperatures. It has always seemed desirable to widen the range of so useful an instrument by a hundred or more degrees, that is, to 450°, and the method usually adopted, is to increase the pressure on the free surface of the mercury and so raise the boiling point. The increased pressure is obtained by filling the tube, above the mercury, with nitrogen. A manufacturing firm of this city has been making this form of thermometer for commercial

purposes, chiefly for use in the metal pots of linotype machines, and has found them to work quite well. After prolonged use, however, what seemed a curious and large error developed itself. If a new and an old thermometer, both having been made of the same stock, under the same conditions, and calibrated alike, were placed in the same bath, the new one was found to read about 17° below the old one. A new and an old thermometer were brought to the University Laboratory for explanation of this error, and it was decided to submit the thermometers to a few simple tests. A description of their construction will first be given.

The bulb part is blown from a hard German glass. It is a short cylinder, about a centimeter long and 5 millimeters diameter. This is fused to a lens front tube of hard American glass. The bulb and tube are filled with mercury in the usual way and the tube drawn out for sealing. A nitrogen bag is then attached, and the bulb cooled to about 7°, allowing the gas to fill the remainder of the tube, under atmospheric pressure, after which the sealing is completed. The instrument is calibrated by comparison with a standard at 16·6° and 100° and the remainder of the scale laid off proportionally. Of course there is chance for serious error here in even approximate work. The coefficient of expansion of mercury has never been measured above 300° and to assume that the relation at low temperatures is the same for higher ones is not warranted. A much more reasonable plan, though still subject to error, would be to ascertain also a fixed point at the upper end of the scale, and then divide proportionally. In this especial case, however, the use of the instrument is largely thermoscopic, and a single mark at the temperature at which it is to be used, would answer as well. The scale is of brass, separate from the thermometer and extended only from 500° to 800° F. It is graduated in 10° spaces, each space being about 3 millimeters. It was not convenient to use this scale, however, so all readings were taken in centimeters from the top of the thermometer, and afterward changed to Centigrade degrees. There were about 27 centimeters of the tube filled with nitrogen at 76 millimeters pressure and a simple calcu-

lation shows that when the mercury column was 5 centimeters from the top, that is, at 430°, there was a pressure of 5 atmospheres. The tension of mercury vapor at 450° is 3400 mm., so that a pressure of 5 atmospheres is none too much to prevent boiling at this temperature. On the other hand Schott* of Jena made use of thermometers of this class in which the initial pressure was 10 atmospheres, and the final pressure 27 atmospheres. This, apparently, was done purposely, in order to see whether a large, even excessive internal pressure would cause an enlargement of the bulb where contraction had formerly been noticed. Wiebe† used thermometers in which the pressures had about the same values as our own. There seems no good reason for using an unnecessarily high pressure, as it has one function only, that is, to raise the boiling point. Three of these thermometers were at our disposal, which we shall refer to as Nos. I, II and III. Thermometer No. I had been in service about three weeks for six or seven hours per day at a temperature of 370°. Nos. II and III were perfectly new. All three were from the same lot, and so far as could be learned were practically identical in construction and calibration.

The glass was immediately suspected as being the seat of the trouble. The motion of the fixed points is no new phenomenon in thermometry. The slow rise of the zero point of ordinary thermometers has often been observed, and we are constantly attending to this error in accurate work stretching over any considerable time. The observations of Dr. Joule on his thermometer, covering a period of thirty-eight years, are most interesting, and are plotted in Curve I, *Fig. 1*, for comparison. It has been customary to assign, as a cause for this phenomenon, the continual external pressure, which caused the bulb to sag inwards. That this is not the case is sufficiently shown by the results obtained by Schott, with the thermometers previously mentioned. With an internal pressure of 26 atmospheres, the zero points

* Schott, *Zeit. für Ins.-Kunde*, X.
† Wiebe, *Ibid.*, XI.

rose 15° after the thermometers had been kept at 470° for two and one-half days and then at 360° for nine days. Wiebe found a rise of the zero point of 21° after a gradual heating to 420°. In this case the internal pressure was about 5 atmospheres. The effect, therefore, was not due to any weakening or softening of the glass, for, in that case, such excessive internal pressures would cause the zero point to fall rather than to rise, and would finally result in rupture. The true cause of the phenomenon has been found to be a question of internal strains. When glass or any other substance of a crystalline nature is heated to plasticity, and then allowed to cool, no matter how slowly, strains are known to establish themselves. Sudden cooling causes them to form at such a rate that fracture may result. On

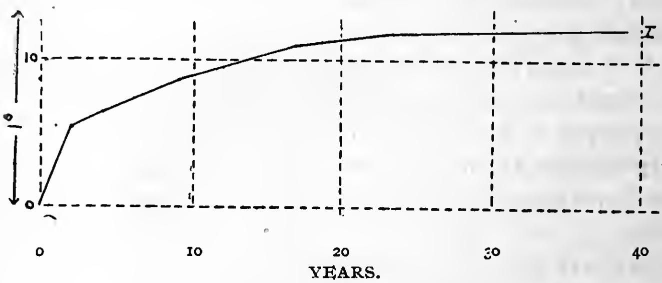

FIG. 1.

the other hand a very slow cooling, that is, the ordinary process of annealing, will often cause them to disappear altogether. In glass, however, they never entirely disappear in any common process of annealing.

Makers of thermometers are accustomed to anneal their glass after blowing, and then, in order to still further eliminate the trouble, allow them to season for at least six months. In the case of Curve I, however, it will be noticed that even after a lapse of thirty years, the curve is inclining upwards appreciably. The forces of restitution are so small that a long interval is necessary for them to effect any results. If, however, we raise the temperature of the glass to a certain point, we allow the reaction to take place at a much greater rate, and this is the explanation of the phenomenon noticed with these thermometers. Moreover,

it has been shown that every glass has a certain temperature at which this increase in the rate of restitution takes place. Schott examined five different specimens of glass, two of which were designed for thermometer construction, viz: Jena Normal Thermometer Glass, and Borosilicate Thermometer Glass 59III. The analyses are given of all five, and it is noticeable that the two thermometer glasses both contain sodium and neither potassium. In fact this writer asserts elsewhere, that a glass with both sodium and potassium in it alwas shows an increased amount of change of the fixed points. He found the Normal glass softened at 400°, and the Boro 59III at 430°. This does not mean that the glass was showing any signs of plasticity, but merely that the strains were weakened, and the molecules rearranging themselves with greater freedom. The method of testing was an optical one, the glass being in the form of blocks. Later, some of the 59III was made into an air thermometer bulb, and placed in a bath which was gradually raised in temperature, in order to test the plasticity. A temperature of about 600° was reached before the pressure began to decrease steadily showing that the glass had become plastic. With glass of this sort, therefore, instruments could be made for temperatures up to possibly 550°, especially if kept at this temperature for a short time only.

THERMOMETERS I, II AND III.

The method of testing was quite simple, as nothing elaborate was desired. It was first thought desirable to have a higher temperature that could be duplicated easily, and mercury vapor was chosen. A boiler which had been prepared for other purposes was used, and gave a known temperature of 357°. Alternate readings were taken in the mercury and steam baths. This was continued until the change seemed to be greatly decreased. With No. III an air bath was used instead of the mercury. A piece of $1\frac{1}{2}$-inch iron pipe, with two Bunsen burners was used, and gave a temperature, that with a small amount of adjusting, varied less than 10° in several hours. It was thought advisable to take readings at the high temperature point, but this could only be

done when the mercury bath was used. It is interesting to note that in Thermometer No. II, the change of this point was about the same as the 100° point, showing a displacement of the whole scale. The barometer was read, and the boiling points corrected. Thermometer No. I, as has been stated, had been in service for approximately 100 hours

TABLE I—THERMOMETER I.

Date.	Temp.	Heating Interval.
Jan. 24	113·1	Ap. 100 hours at 370°
Jan. 25	114·6	1 hour at 355°
Mar. 8	115·3	½ hour at 355°
Mar. 8	115·0	8 hours at 370°

TABLE II—THERMOMETER II.

Date.	Temp.	Heating Interval.	Bath.
Jan. 24	100·	0 hours	Steam
Jan 28	349·4	30 minutes at 357° ap.	Hg.
	101·1		S.
	349·4	30 minutes " "	Hg.
Jan. 29	103·9		S.
	351·7	30 minutes " "	Hg.
Jan. 30	103·9		S.
	353·3	30 minutes " "	Hg.
Jan. 31	105·0		S.
	353·9	1 hour " "	Hg.
Feb. 1	105·0		S.
Feb. 2		4 hours " "	Hg.
Feb. 5	106·6		S.
	355·5	7 hours " "	Hg.
Feb. 20	107·7		S.
	358·8	7 hours " "	Hg.
Feb. 21	108·3		S.
Feb. 25	358·3	13 hours " "	Hg.
Feb. 26	108·3		S.
Mar. 12	375·0	8·5 hours " "	Air
Mar. 13	110·0		S.

TABLE III.—THERMOMETER III.

Date.	Temp.	Heating Interval.
Mar. 19	99·1	0 hours
	114·3	5 hours at 410°
Mar. 20	113·2	
	116·2	5 hours at 410°
Mar. 21	115·7	
	117·3	7 hours at 400°
Mar. 22	116·6	
	118·1	5 hours at 400°
Mar. 23	118·0	
	118·3	3·5 hours at 420°
Mar. 25	118·2	
	118·8	7 hours at 415°
Mar. 26	118·3	
	118·3	8 hours at 430°
Mar. 27	118·4	

at 370°. This was not continuous use, but at intervals of six to seven hours per day. There is little reason, however, why this should make any difference in the final effect, as the action is continuous. Little testing could be done, and but four readings were taken. The maker had etched marks at the six points 16·6°, 100°, 183·3°, 266·6°,

349·9° and 433·2°. They were at equal distances apart, the 16·6° and 100° points being obtained by comparison with a standard, as stated. The readings taken are shown in Table I. It is necessary to remember that readings had to be taken by an auxiliary scale, and are probably accurate to a quarter of a millimeter. Now since one degree is about ·5 millimeter, we are reading to about a half degree. Therefore, the last two temperatures of Table I must be considered as showing little or no change, especially as the last one after eight hours at 370°C. shows a slight drop instead of a rise. The column "Heating Interval" means that the corresponding temperature reading had been taken after

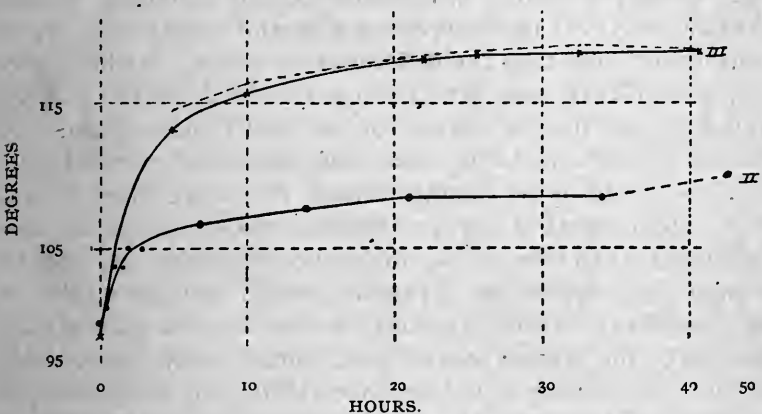

FIG. 2.

the thermometer had been kept at the high temperature for the indicated hours. The steam readings were usually taken about fifteen hours after the thermometer had cooled.

Table II shows the readings taken with Thermometer II. The steam readings are plotted in Curve II, *Fig. 2.* Though the last two readings are identical, we might confidently expect that a higher temperature and prolonged heating would show a further rise. It would be very slight, however, for the thermometer has evidently reached a nearly permanent state. Readings would have been continued had not an unfortunate accident put the thermometer out of service. The dotted portion of Curve II shows a reading

that was taken after the thermometer was broken. It shows a considerable rise, but the writer is not sure that an accurate measurement could be made on the thermometer in its broken condition. Thermometer III was obtained at this time, and was from the same lot as No. II, and the readings on this instrument are shown in Table III and Curve III, *Fig. 2*. There was no essential difference in the treatment from that of No. II except that the air bath was used entirely and the temperature of the heating bath was from 50° to 60° C. higher. This does not account, however, for the great difference in the displacements of the scales. Evidently No. III has had a different history from No. II. No. III may possibly have been cooled suddenly or unequally, or No. II may have had a partial annealing. It is more than likely that the difference was made in the blowing, as a draft of cool air striking the bulb while cooling would cause the formation of an additional strain. It should be noticed that no such difference as Curves II and III show could be on account of the treatment after calibration. Heating at a higher temperature would cause the displacement to take place in a shorter time, and would change the shape of the curve, but would have no effect on the final result. This is evident when we remember that heating to the plastic point would immediately relieve the strains. Moreover, this difference should not be counted in any way as a defect in the thermometers, for in either case, after heating, we have what is desired, a practically permanent calibration. It should be stated here that a large number of these thermometers have been made, and that the displacement is usually about 18°. No. II, therefore, shows an unusually small displacement. The dotted curve of No. III shows the readings obtained immediately after the heating, and are invariably higher, as would be expected.

These thermometers were made, as stated, of ordinary hard glass, and it is interesting to note some comparisons that have been made of this effect in several varieties of glass. According to Wiebe we have for Jena Normal Thermometer Glass a rise of the zero point of ·04° in 285 days at ordinary temperature; Thüringen Glass, a former

standard German glass, showed six times as much, and English glass four times as much. On heating the three varieties for nineteen hours at 360°, the Jena thermometer rose 2·21°, and the Thüringen 7·30°, or more than three times as much. These experiments also showed that all the thermometers had a tendency towards a more or less fixed position of the scale, after prolonged heating at a high temperature. Borosilicate, 59III and Baryt-Borosilicate 122III are two other varieties of thermometer glass which are made at the Jena factories. Less information of these varieties is at hand than some of the others. Wiebe took two thermometers of 59III, one made in the ordinary way, and the other "fine annealed," and found after thirty hours' heating at about 300° that the former zero had risen 3·9°, and the latter ·2°. A thermometer made of Baryt-Borosilicate 122III was kept at 325°, and the zero had risen ·21°, ·45° and ·51° after eighteen, forty-four and sixty hours respectively. Apparently this is the most nearly perfect glass for thermometers.

From preceding statements we can see that the amount of scale displacement varies greatly in different varieties of glass. Much advantage is to be had by using a glass made according to a formula, such as the Jena glasses, not only on account of the decreased amount of the displacement, but also on account of the regularity of the product. The standard thermometer glass in Germany to-day is probably Borosilicate 59III, chiefly on account of its high fusing point and low coefficient of expansion. By constructing a thermometer of such a glass, we are able to predict just how, and to what extent, changes will take place. Of course there can be no such regularity in glass made in a more haphazard way, and containing materials which experiment shows to be deleterious; as, for example, the presence of sodium and potassium in the same glass. The great difference in the amount of scale displacement indicated by Curves II and III has been shown to be due, not to irregularity in the material, but more likely to a lack of uniformity in the construction. We may be certain that there are several particular operations essentially necessary

for the construction of a thermometer which is to be accurate and nearly permanent. The glass should be well selected; the empty bulb and tube after being prepared for filling should be carefully annealed by a very slow cooling process. After being filled and sealed, the thermometer should be kept at as high a temperature as convenient, and for a time depending on this temperature. For thermometers not to be used over 100°, probably the present method of seasoning is sufficient, although the seasoning would be hastened, and be more complete if allowed to take place at a higher than room temperature. For high-temperature thermometers it is essential that they be kept at about 450° for three or four days. This is comparatively easy, and cheap if an air bath be used, and would obviate the difficulty which has been described. Thermometers after such treatment could be calibrated for high temperatures and be expected to change little during a long period of time. A volume written by Hovestadt on Jena glass no doubt contains much information on this subject, but the writer saw the book too late to do more than glance through it.

OBITUARY.

DAVID SHEPHERD HOLMAN.

David Shepherd Holman, who was Actuary to the Franklin Institute from 1871 to 1885, died at Bangor, Me., on May 13, 1901.

Mr. Holman was born in Milo, Me., in 1826, and at the time of his death was in his seventy-fifth year. He became identified with the Institute as a member in 1866, and at once took an active interest in its work. Although he was to a great extent self-educated, and had not enjoyed the advantages of early scientific training, he succeeded in becoming a skillful microscopist, and, being gifted with great mechanical ingenuity, devised a number of useful microscopic accessories, with some of which his name is associated. Of these, perhaps, the best known are the so-called "Holman life-slides," which he devised for the pur-

pose of facilitating the study of the vital functions in living animals. He also originated other devices and methods for illustrating the circulation of the vital fluids in animals and plants, which gained for him considerable local repute.

He was mainly instrumental in the foundation of the Optical Section of the Franklin Institute, in the year 1872, the first Section to be founded in the Institute. The force of his personal enthusiasm gave to this Section a notable career for several years.

Mr. Holman was among the first to foresee and appreciate at their true value the great advantages of the typewriting machine at the time of its first introduction, and when the future of this great time- and labor-saving device was still problematical. From the beginning, his faith in the universal applicability of the typewriter, with the supplementary aid of stenography, was unbounded. He gave practical form to his ideas on this subject by founding, in 1873, at the Institute, a school of stenography and typewriting, which soon

was largely attended and most successful. All this seems but a commonplace matter from the point of view of to-day, but the local stimulus that Mr. Holman's pioneer work gave to the modern art of correspondence was unquestionably of great value, and he is entitled to the fullest recognition for this service.

After the severing of his official connection with the Franklin Institute in 1885, Mr. Holman became associated with the Atlantic Refining Company, and for a number of years was in charge of a laboratory which he equipped for testing the viscosity and other physical properties of mineral oils. While in this position he devised a "viscosi-

meter," known by his name, which depended for its operative feature on the time required for the descent of a metal sphere through a column of given height of the oil under examination.

Later, Mr. Holman was appointed instructor in stenography and typewriting in Girard College, which position he occupied for several years. He also became actively interested in the Academy of Natural Sciences of Philadelphia. For a number of years, also, he was in the lecture field, where his skill as a demonstrator with the projecting microscope enabled him to achieve considerable success as a teacher and experimenter.

During his official connection with the Franklin Institute, extending over fifteen years, Mr. Holman's obliging disposition and unvarying amiability made him many friends, who will sincely mourn his loss.

LOUIS E. LEVY,
WM. H. WAHL,
H. R. HEYL,
Committee.

COMMITTEE ON LIBRARY.

Stated Meeting, held Monday, June 10, 1901.

The Librarian reported the following additions to the library during the month of May:

	Bound vols.	Unbound vols.	Pamphlets.
By gift	32	10	91
" purchase	2	—	—
From the JOURNAL	2	5	—
	36	15	91

Total additions for the month 142

Gifts were reported from the Ammonia Co. of Philadelphia; Dr. H. Kammerlingh-Onnes of Leyden, Holland; Dr. Wm. H. Greene; Messrs. Samuel Sartain, C. W. Swoope and Lewis S. Ware. The usual monthly receipt of United States Government publications and exchanges was reported.

W.

NOTES AND COMMENTS.

POWER FROM BLAST-FURNACE GAS.

The *Iron Age* makes the following interesting editorial comments on the progress made in Germany in connection with the utilization of blast-furnace for power as described in a recent paper, by Herr F. W. Luermann, before the *Verein Deutscher Eisenhüttenleute*, viz.: Herr Luermann, after some incidental reference to the apparent inactivity in this field of American engineers, records the fact that furnace gas engines to the extent of 77,545 horse-power have been delivered or are under construction in Europe, Germany being credited with 44,665 horse-power, while Great Britain is in the list with 600 horse-power. The editor believes, however, that the apathy of American furnace managers is much more apparent than real. Engine builders and iron makers are somewhat mysterious as to what they are really doing. Suffice it to say that our engineers are not by any means satisfied with the designs brought forward, particularly in blowing engines, and that quietly a good deal of work is being done.

Luermann has been doing splendid work as a recorder of current progress and his latest paper, the third of the series, brings developments close up to date. His reports are all the more interesting and valuable since he is not in any way connected with any make of gas engine, and occupies the position of an independent and a frank critic.

At the outstart Luermann took the ground that the furnace gas must first be thoroughly cleaned not only of dust, but also of metal vapors and of steam. He draws the conclusion from the experience gathered in practice thus far that fluctuations in the composition of blast-furnace gas have no appreciable effect, and further, that the low calorific value of some gases is no serious obstacle, a Koerting engine, for instance, being operated at the Mansfeld copper smelter at Eisleben with gas having only 700 heat units per cubic meter.

The cleaning of the gas, however, is now acknowledged to be a vital point. Luermann describes the Kloenne washer, the Theisen centrifugal machine, the plant at Frieden, Gutehoffnung, and Georg-Marie works, which are pronounced the most elaborate in Germany. At Differdingen the first catching and cooling installation proved inadequate and the records show that the blowing engines did not run as steadily as the gas engines used for operating dynamos.

Luermann also describes the different types of gas engines in use, the Seraing, the Oechselhaueser, the Koerting and the Nuernberg. The question of water cooling the piston is one which seems to have come forward lately, and the conclusion has apparently been reached that up to a certain size of cylinder, such precautions are not necessary.

It seems that designers are also turning to the question of reducing the waste of gas at the tunnel head by more elaborate and efficient arrangements.

Luermann reports that data relative to the consumption of gas in engines are not yet numerous and vary from 2·56 centimeters to 3·67 centimeters per

horse-power. With the high cost of coke in Germany, the saving figures out about $1.50 per ton of pig iron produced, which is certainly a very tempting sum.

There can be no doubt but what the utilization of the waste gas from the blast-furnace for the operation of blowing engines, for the production of electric power, and possibly for the manufacture of calcium carbide, has proved practical. While our lower fuel cost does not hold out so large a saving as that realized in Europe, and while the powdery ores of many of our leading districts threaten to give us special trouble, it seems absolutely necessary that our gas engine builders on the one side and our furnacemen on the other, must soon seriously attack the problem of adapting these improvements to our special conditions.

BOOK NOTICES.

Elaboration des Metaux dérivés du Fer. Réactions métallurgiques. Par L. Gage, Capitaine d'Artillerie. Petit in-8, avec 17 figures (*Encyclopédie scientifique des Aide-Mémoire*). Broché, 2 francs 50 cent.; Cartonné, 3 francs.

Elaboration des Metaux derives du Fer. Foyers métallurgiques. Par L. Gages, Capitaine d'Artillerie. Petit in-8, avec 22 figures (*Encyclopédie scientifique des Aide-Memoire*). Broché, 2 francs, 50 cent.; Cartonné, 3 francs. Paris: Libraire Gauthier-Villars. 1901.

These volumes constitute the latest additions to the Encyclopédie Scientifique des Aide-Mémoire, of which many previous numbers of the series have been noticed in this column.

The volume first named is devoted to the subjects of fuels, natural and artificial, furnaces of various types and refractory materials.

The second volume is devoted to the various procedures for the production of iron and steel. Each volume of this series is complete in itself.

W.

Atoms and Energies. By D. O. Murray, A.M., Sometime Instructor in the Government Shogyo Gakko, Kyoto, Japan. 8vo, pp. 200. New York: A. S. Barnes & Co., 1901. (Price $1.25.)

The author seeks in this work to establish the probability of certain views respecting the nature of matter and energy radically different from those generally accepted. In Chapter I he starts with the proposition that the terms Large and Small are merely terms of comparison, not abstract dimensions. An atom, consequently, must be very large as compared with some other size. He maintains as a consequence of this assumption, that atoms in solids are in actual contact. In Chapter II, the author considers the question of the shapes of atoms, and reaches the conclusion that the determining effect upon their interactions and relations is conditional upon their size and shape. Chapter III deals with the subject of chemical affinity, in which the ground is taken that differences in shape suffice to account for all the phenomena. Chapter V seeks to identify the simple energy that produces the results of chemical affinity, with the attractive energies known as cohesion, adhesion and gravitation. Chapter VI discusses expansive energy; Chapter

VII, electricity and magnetism; Chapters VIII and IX, the three states of matter; Chapter X, vibration. Chapter XI concludes the work, and in this it is sought to be shown that energy cannot be considered merely as a mode of motion, that it is not merely an attribute of matter, but is a distinct entity.

W.

Select Methods in Food Analysis. By Henry Leffmann, A.M., M.D., and William Beam, A.M., M.D. 8vo, pp. 383. Philadelphia: P. Blakiston's Son & Co., 1901.

"This book is intended to be a concise summary of the analytic methods adapted to the needs of both practising analysts and advanced students in applied chemistry," and it must be admitted that this aim has been fully attained by the authors.

The principal methods of food analysis, especially those practised in American and English laboratories, are well selected and carefully described. The arrangement, too, is excellent.

Sixty-seven pages of the book are devoted to the description of general or more frequently recurring physical and chemical determinations, and these are followed by a very interesting chapter on the detection of poisonous metals, coloring matters, and preservatives. The special methods employed in the examination of the various articles of food constitute the bulk of the work. This includes the following subjects—starch and materials used in bread-making, fats and oils, milk and milk products, non-alcoholic beverages, condiments and spices, alcoholic beverages, and flesh foods.

While the description is concise, it appears to contain all that is essential to the obtaining of good results by an expert analyst, and, inasmuch as many data and processes from official sources (*e. g.* the United States Department of Agriculture and the Association of Official Agricultural Chemists) are made more accessible to chemists than are the original bulletins, we venture the prediction that this volume will soon be found within easy reach on the book-shelves of every English-speaking food analyst. H. F. K.

Induction Coils: How to make, use and repair them. Including Ruhmkorff, Tesla and medical coils, Roentgen radiography, wireless telegraphy and practical information on primary and secondary batteries. By H. S. Norrie (Norman H. Schneider), second edition, revised and much enlarged. 12mo, pp. 269. New York: Spon & Chamberlain; London: E. & F. N. Spon. (Price, cloth, $1.00.)

The author explains that his inducements to prepare a second edition of his work were, in part, the great favor with which the first edition was received, and partly the steadily growing interest in the subject which has been manifested in the scientific activity and numerous improved forms of apparatus that have been made known within the past few years. The author in his endeavor to bring the volume up to date, has thoroughly revised it, partly rewritten it, and added considerable new matter with numerous new illustrations.

Considerable space in the new matter is given to the following: Medical and bath coils, gas engine and spark coils, contact-breakers, primary and

secondary batteries, electric gas lighting, new methods of X-ray work and a complete chapter on wireless telegraphy. A complete index, contents, list of illustrations and contents of tables have been added. W.

Les Discharges Electriques dans les Gaz. Par J. J. Thomson, P.S.C., F.R.S. Ouvrage traduit de l'Anglais avec des Notes, par Louis Barbillion, Dr. es Sc., et un preface par Ch. Ed. Guillaume. Paris: Gauthier-Villars 1900.

This translation of Dr. Thomson's "Electrical Discharges in Gases" should be readily appreciated by French readers. The work is well known and esteemed as a scientific classic by English students of electrical science.

W.

Elektrische Verbrauchsmesser der Neuzeit für den praktischen Gebrauch dargestellt von Johannes Zacharias, Ingenieur. Mit 194 Abbildungen im Text und zahlreichen Tabellen. Halle a/S. Verlag von Wilhelm Knapp, 1901. (R.M., 15.)

The literature relating to electric meters is extremely meagre, and the present work will undoubtedly prove of much value to electrical engineers. The compilation of patent data appended to the descriptive portion of the work is a feature which will be highly appreciated by all who have occasion to look into the history of the subject. W.

Recueil de Problèmes de Géométrie Analytique a l'usage des Classes de Mathématiques Spéciales. Solutions des Problèmes donnés aux Concours d'admission à l'École Polytechnique de 1860 a 1900. Par François Michel, Ancien Élève de l'École Polytechnique, Inspecteur de l'Exploitation aux Chemins de fer du Nord. Un volume in-8, avec 60 figures. 1900. 6 francs. Paris: Librairie Gauthier-Villars.

This volume contains the problems and their solution which had been given to the candidates for admission in the *École Polytechnique* from the years 1860 to 1900 inclusive. W.

Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, June 19, 1901.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, June 19, 1901.

President JOHN BIRKINBINE in the chair.

Present, 84 members and visitors.

Additions to membership since last month, 12.

The special committee named at the previous meeting, to prepare a memorial of the late David Shepherd Holman, one time Actuary of the Franklin Institute, presented a report, through its Chairman, Mr. L. E. Levy, which was accepted and the committee discharged with thanks.

Prof. Lewis M. Haupt presented a communication entitled, "Obstructions to Commerce." The speaker discussed in a general way the various natural impediments to free commercial intercourse, dwelling especially upon the obstructions offered by continental barriers, and harbor entrances. The subject was profusely illustrated with the aid of lantern slides, and is reserved for publication in full. Discussed by Messrs. L.E. Levy, the President and the author.

Mr. Edwin S. Church, superintendent of machinery of the U. S. Mint at Philadelphia, presented an account, freely illustrated with lantern slides, of the engineering equipment of the New Mint, discussed by Professor Haupt, Messrs. O. E. Outerbridge, Washington Jones, Sam'l R. Marshall and the author. (Referred for publication.)

Adjourned.

WM. H. WAHL,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of proceedings of the stated meeting held Wednesday, June 5, 1901.*]

The following reports were adopted:

(No. 1792.) *Electric Liquid Healing Process.*—Geo. D. Burton, Boston, Mass. Dismissed.

(No. 1992.) *System of Oil Heating and Incandescent Lighting.*—Arthur Kitson, Philadelphia.

ABSTRACT.—This invention is the subject of numerous patents granted to applicant, dating from 1888 to 1899, copies of all of which are filed with the papers of the case. The report gives an exhaustive account of the history of the art, which may be summarized in the following abstract from the same: The application of Mr. Kitson in this case was for an award to him as the original inventor of a lamp and system for burning kerosene oil under a mantle to produce an incandescent light, the oil being under suitable pressure and vaporized at the lamp before being burned. After a very careful and thorough study of the facts, the Sub-Committee finds it impossible to make an award to Mr. Kitson as the original inventor of such a lamp and system. The Sub-Committee does believe it proper, however, to recognize the merit which is shown in the perfection of a lamp which satisfactorily vaporizes and uses kerosene oil for incandescent mantle lighting and its commercial success in competition with other artificial illuminants, and, therefore, recommends the award to the inventor of the Edward Longstreth Medal of Merit. [*Sub-Committee*—Arthur J. Rowland, Chairman; Chas. A. Hexamer, L. L. Cheney, Geo. A. Hoadley, Geo. F. Stradling, Wm. McDevitt, Frank P. Brown.]

(No. 2134.) *Improvements in Musical Instruments.*—Chas. F. Albert, Philadelphia. (Referred by the Jury of Awards, National Export Exposition.)

ABSTRACT.—This report refers to the fact that the general excellence of the musical instruments made by Mr. Albert has already been recognized by

the grant of the highest award in the gift of the Institute. The exhibit, however, embraced one invention of importance which had not previously been brought to the Committee's attention, namely, Mr. Albert's triple-covered flexible G strings for violins, violos and cellos. This invention consists in covering gut or other strings for musical instruments with silk thread or its equivalent, and in covering the thread-wrapped string with two wires, whereby certain positive advantages are secured. There were other minor features included in the invention.

The serious defect in all similarly wrapped strings lay in the fact that the drying of the gut core caused the loosening of the single wire wrapping, so that it would roll under the friction of the bow, and rattle, thus destroying its tone qualities. This and other defects, it is admitted, are corrected by Mr. Albert's invention, and his triple-wound G strings have come into general use. The award of the John Scott Legacy Premium and Medal is recommended. [*Sub-Committee.*—H. R. Heyl, Chairman; Wm. Stoll, Jr., Chas. M. Schmitz, Paul Sentz, Richard Zeckwer, Henry C. Wilt.]

(No. 2175.) *Balance for Testing White Metal Alloys.*—Joseph Richards, Philadelphia.

This report is reserved for publication in full. The award of the John. Scott Legacy Premium and Medal is recommended. [*Sub-Committee.*—H. F. Keller, Chairman; F. Lynwood Garrison, G. H. Clamer.)

(No. 2178. *Automatic Micrometer Rolling Mill Gauge.*—Robt. B. Haines, Philadelphia.

A re-investigation, The award of the John Scott Legacy Premium and Medal is recommended in view of the fact that the invention having come into universal use in the United States, and to some extent also in Europe, has demonstrated high utility for its intended service. [*Sub-Committee.*—James Christie, Chairman; Thos. P. Conard, A. Falkenau.]

The following reports passed first reading:

(No. 2151.) *Tobacco Cutting Machines.*—John B. Adt, Baltimore, Md.

(No. 2148.) *Damper Regulator.*—N. C. Locke, Salem, Mass.

Made advisory and adopted. The reason assigned in the report is that applicant has presented no new data.

(No. 2179.) *Combustion Crucible,*—Porter W. Shimer, Easton, Pa.

(No. 2188.) *Electrolytic Production of Metals and Nitric Acid from Fused Nitrates.*—James D. Darling, Philadelphia.

(No. 2113,) *Liszt Organs.*—Mason & Hamlin Company, Boston, Mass, Referred back to the Sub-Committee for amendment.

The following cases were dismissed:

(No. 1859.) *Safety Device for Elevators.*—S. D. Strohm, Philadelphia, Pa.

(No. 1883.) *High Tension Storage Battery.*—N. H. Edgerton, Philadelphia.

(No. 1971.) *Synchronograph.*—Geo. O. Squier and Albert C. Crehore, Fort Monroe, Va.

(No. 2080.) *Sterilizing Apparatus.*—Jas. E. Thomas and Elisha P. Grow, Philadelphia.

(No. 2104.) *Gas and Oil Heater.*—Joshua J. Nix, Royersford, Pa.

(No. 2176.) *Typewriter.*—W. T. Hoofnagle, New York, N. Y.

JOURNAL

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FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CLII, No. 2. 76TH YEAR. AUGUST, 1901

PHYSICAL SECTION.

Stated Meeting, held Wednesday, May 22, 1901.

A SYSTEM OF CORRECTIONS FOR HEAT LOSSES IN CALORIMETRIC EXPERIMENTS.

BY JOSEPH W. RICHARDS,
Member of the Institute.

In 1892, the writer, conjointly with Prof. B. W. Frazier, began experiments in the metallurgical laboratory of the Lehigh University, having for their object the determination of the specific heat of copper at high temperatures, in order to render it reliably available as a substitute for platinum in pyrometry, by the method of mixtures.

To this end, the amounts of heat given out by copper and platinum from various temperatures were measured, using a copper and a platinum ball in each experiment, and then, using Violle's formula for the mean specific heat of platinum, the temperature of the experiment was calculated and thence the mean specific heat of the copper from that

temperature. The final result obtained for the specific heat of copper was

$$Sm\ (0\ \text{to}\ t^0) = 0{\cdot}09393 + 0{\cdot}00001778\ t.$$

By the aid of this formula, copper becomes available for pyrometry for temperatures nearly to its melting point, say to 1000° C. or even to 1050°, with a degree of accuracy quite sufficient for most technical purposes.

In the conduct of these experiments, the need was felt of a better system of corrections for the heat lost to the calorimeter during the experiment. The calculation of the water-value of calorimeter from the weights and known specific heats of its various parts is evidently an unsatisfactory approximation only, for heat is conducted unequally fast to the various parts because of their varying conductivity, some parts (as the thermometer stem) are partly inside and partly outside the calorimeter; and, finally, the very instant that the body of the calorimeter begins to rise in temperature ever so little, it begins also to radiate heat to its envelope—and these radiation losses are evidently not only functions of the rise of temperature, like the water-value of the calorimeter body, but also functions of the time. The corrections for heat losses during an experiment are therefore inherently time functions, being properly expressed for a given calorimeter, as so many calories at the end of 1, 2, 3, 4, 5, 10, etc., minutes after starting, per degree rise of temperature at that time, above the starting temperature.

The calorimeters used in this laboratory are of three sizes, consisting of an inner vessel of brass, covered with paper, and resting on three wooden props, contained in a walnut casing, the interspace being filled with cotton wadding. They were patterned after the calorimeters used by Andree and Ackerman, in their experiments on iron and blast-furnace slags, and fully described with illustrations, in the *Jernkontoret's Annalen*, 1884, p. 73, and 1886, p. 1. Since the systems of corrections to be described in this paper are applicable to any form of calorimeter whatever, working on the principle of mixtures, the particular kind of calorimeters

in which it was worked out is of secondary importance, and if further details are desired, reference is made to the above journal.

Our method of determining the water-values of our calorimeters for 1, 2, 3, etc., minutes after starting is purely *experimental*, and the method of procedure finally settled on is as follows: The calorimeter is taken empty and placed in a cool room, kept at a constant temperature. The stirrer is operated from time to time, and readings taken until it is seen that the temperature is constant to within say 0·01° in five or ten minutes. In an adjoining room, kept at a higher temperature, is a can of water provided with a stirrer, an accurate thermometer which has been previously compared with the thermometer in the calorimeter, and an outlet beneath with a stop-cock. This water being at a steady temperature, or very nearly so, the experiment can be made. The final temperature of the empty calorimeter is taken, it is carried to the next room, and filled with the water at the known higher temperature. The time of *beginning* the filling is accurately noted, also the temperature of the water just before running in. The calorimeter is then stoppered, carried back, stirred and readings taken at exactly at 1, 2, 3, 4, 5, 10, 15, 20, 25 and 30 minutes after the filling was started, the temperature of the room being kept as nearly constant as possible. This procedure, taken altogether, represents exactly the manner in which actual experiments with the calorimeter are afterwards carried out, and therefore the heat losses obtained from this running in of water into the empty calorimeter will represent exactly the heat losses in an actual experiment.

The data obtained will be as follows:

(1) The temperature of the empty calorimeter (t_0).

(2) The temperature of the warm water run in (T).

(3) The observed temperatures at 1, 2, 3, etc., minutes after (t_1, t_2, t_3, etc.).

The calculations will be as follows:

(4) The warm water has fallen from T° to t_1, t_2, t_3, etc., giving up

in 1 minute $W \times (T - t_1)$ calories.
" 2 minutes $W \times (T - t_2)$ " etc.

We thus know accurately the total number of calories lost to the calorimeter at the end of 1, 2, 3, etc., minutes.

(5) The body of the calorimeter has risen, meanwhile, from t_0 to t_1, etc., having thus been heated through

in 1 minute — $(t_1 - t_0)^\circ$
" 2 minutes — $(t_2 - t_0)^\circ$ etc.

(6) Dividing the total calories lost to the calorimeter in the first minute, as obtained in (4), by the rise in temperature of the body of the calorimeter above its starting temperature as obtained in (5), the quotient is the heat lost to the calorimeter at the end of one minute, per degree rise of the calorimeter above its starting temperature; or we might call it briefly "the water-value of the calorimeter *for one minute*." Similar calculations give us its water-value to the end of 2, 3, 4, 5, etc., minutes from starting.

These values represent all losses of every kind, and allow also for the heating up caused by stirring or the proximity of the operator; in fact, it is only necessary to determine these corrections, repeating exactly the conditions of an experiment, in order to have a practically perfect system of corrections.

EXAMPLE.

Water used . . . = 245·2 grams.
Temperature . . = 23·69¼, Geissler thermometer.
= 23·23¼, Baudin " (used in calorimeter.)

Time.	Calorimeter.					
4·55	18° 21	(Temperature of room, 18·5°.)				
·57	·22	Rising at 0°·00½ per minute.				
·58½	·22¾					
·59	18°·23	Fall of Water.	Calories Lost.	Apparent Rise.	Corrected Rise.	Water Value Per 1° Rise.
1 minute	22° 87	0° 36¼	88·9	4°·64	4·63½	19·2 Calories
2 "	·77	0° 46¼	113·4	4°·54	4·53	25·0 "
3 "	·71	0°·52¼	128·1	4°·48	4·46½	28·7 "
4 "	·68	0° 55¼	135·5	4°·45	4·43	30·6 "
5 "	·64½	0° 58¾	144·0	4°·41½	4·39	32·8 "

A number of such experiments were made on each calorimeter, using widely different ranges of temperature; the calculations showed that the heat losses up to any given time were proportional to the range, within the experimental errors. Thus, for example, the two-minute correction determined in differing experiments was

	Calories per 1° rise.
With a range of 2°·10	28
" " " " 2°·95	27
" " " " 6°·57	27·7
" " " " 7°·18	26·8
" " " " 9°·96	26·8
2′ correction finally adopted	27·0

The method of using the corrections thus obtained is susceptible of several variations; we found the following to be the most satisfactory:

An experiment being made (in pyrometry, for instance, with a copper ball) and the readings taken at 1, 2, 3, etc., minutes after immersion of the ball, these readings are first corrected for the previous rate of rise or fall of the calorimeter. The corrected readings, minus the temperature before immersion, give the corrected rise of temperature to the end of the different minutes. The calories lost to the calorimeter to the end of any given minute is the correction for that minute multiplied by the corrected rise at the end of that minute. The heat still left in the calorimeter is, of course, the weight of water multiplied by the corrected rise. The sum of these two quantities gives the total heat given up to the calorimeter by the copper ball, when cooling to the temperature it has at the end of the given minute. But this is inconvenient, because the heat values thus obtained from readings for the different minutes are not strictly comparable, since the copper ball is at different temperatures at the end of each minute.

A more satisfactory method of using the corrections is to calculate by their aid *the theoretical temperature which the mixture (water plus copper) would have had if no heat at all had been lost to the calorimeter.* To do this, we reason that if the

heat lost to the calorimeter had not been lost, it would have raised the temperature of the water and copper a certain amount higher than it actually went. The number of calories lost to the calorimeter to the end of any given minute is therefore calculated, as before, and then this quantity is divided by the water value of the water and copper together. The number of degrees thus obtained, added to the rise of temperature which actually occurred at the close of that minute, gives us theoretically the rise of temperature which would have occurred had *no* heat been lost to the calorimeter. This is then the theoretical temperature of the mixture at zero minutes, with no losses of heat. But, every observation made, when thus reduced, gives us theoretically the *same* temperature, *i. e.*, the theoretical rise, and we have therefore as many experimental values of this quantity as we have taken observations; every observation gives us a value for this quantity, whether taken at one minute or at thirty. Slight variations in the values thus obtained are inevitable, but the fullest opportunity is thus afforded to discuss the observations and to deduce from them the most probable value of the theoretical rise. The one-minute reading, when copper is immersed, is usually identical with the later readings; but, when platinum is used this reading gives a lower corrected value than the subsequent ones, because the platinum has not yet given out all its heat, in the one minute. A still poorer conductor, like fire-clay, does not become equalized in temperature for several minutes, and the theoretical rise will be observed to increase gradually for those minutes, to become *constant* thereafter, when the clay has given out all its heat. If the outside temperature changes during the experiment, the theoretical rise will gradually increase or diminish with increasing time; in such cases, the later readings can be discarded; or, in an extreme case, the earliest reliable or constant readings alone taken.

The following illustration of the method of using these corrections is taken from an actual experiment made in the open air in the yard of the Bethlehem Steel Company, to determine the temperature of the gases escaping from flues

of boilers attached to a blast-furnace. A copper ball was put into an iron box on the end of an iron rod, inserted twenty-seven minutes in the chimney flue, then withdrawn and dropped immediately into the calorimeter.

Weight of copper cylinder	21·803	grams.
" " water used	301·80	"
Water value of copper cylinder	2·06	"
Calorific capacity of water and copper	303·86	"

Record.

5·13 = copper put into the flue.

	Calorimeter.	Rise per minute.	
5·30	16°·63	0°·02	Average 0·°019
·35	16°·73		
·40	·82	0°·018	

5·40¼	**16·825** (calculated)—Cylinder introduced.		
·41¼	21·62	Corrected for previous rate of rise.	21·601
·42¼	·56		·522
·43¼	·53		·473
·44¼	·51¾		·441
·45¼	·50		·405

CALCULATIONS.

Minutes.		Rise.	Corrections.	Theoretical Range.	
0	. . . . . 16·825				
1	. . . . . 21·601	4·776	0·324	5·100	Average **5·105**
2	. . . . . 21·522	4·697	0·413	5·110	
3	. . . . . 21·473	4·648	0·454	5·102	
4	. . . . . 21·441	4·616	0·486	5·102	
5	. . . . . 21·405	4·580	0·530	5·110	

The corrections were made as follows:

	Water Value of Calorimeter.		Rise Above Starting.		Calories Lost to Calorimeter.		Water Value of Water + Copper.		Correction.
1′	. . . 20·6	×	4·776	=	98·39	÷	303·86	=	0°·324
2′	. . . 26·7	×	4·697	=	125·41	÷	"	=	0°·413
3′	. . . 29·7	×	4·648	=	138·05	÷	"	=	0°·454
4′	. . . 32·0	×	4·616	=	147·71	÷	"	=	0°·486
5′	. . . 35·2	×	4·580	=	161·22	÷	"	=	0°·530

Theoretical rise	5°·105
Starting temperature	16°·825
Theoretical end temperature	21°·930
Calories given out to this temperature = 301·8 × 5·105 =	1540·69
Equal to, per gram of copper	70·665
Add heat in 1 gram of copper from 0° to 21·°93	2·07
Heat in copper, 0° to t = ...	**72·735** Calories

Hence

$$0{\cdot}09393\,t + 0{\cdot}00001778t^2 = 72{\cdot}735$$

and

$$t = 685{\cdot}^\circ 5$$

This experiment has been quoted in full, as it explains not only the method of making the corrections, and of using copper as a pyrometric material, but it also shows the accuracy of the system of corrections under trying circumstances. The calorimeter was rising at the comparatively rapid rate of two-hundredths of a degree per minute, and readings of the thermometer were estimated to the nearest quarter of a hundredth, but these were not very certain, yet the five corrected readings have an extreme variation of only one hundredth (0·2 per cent.) and the extreme variation from the mean was only half an hundredth (0·1 per cent.). It is very likely that the heat in the copper as it entered the calorimeter was determined to 0·1 per cent.

Experiments in the laboratory under more favorable conditions as regards external temperature and steadiness of the calorimeter have given still closer results. A score of experiments could be quoted where the maximum variation between the various corrected readings was under 0·1 per cent. I quote a few to show particularly that the corrections apply as accurately to high ranges as to low ones:

2′			1°·885	6°·111	7°·417	
3′			1°·888	6°·122	7°·416	7°·779
4′		1°·221	1°·888	6°·123	7°·416	7°·785
5′		1°·222	1°·888	6°·122	7°·416	7°·781
6′	0°·540	1°·222				
7′	0°·541	1°·221				
8′	0°·541					
9′	0°·542					
10′	0°·542					

The last one given is particularly interesting, in that it was a reversed experiment, in which ice was put into the calorimeter and its temperature fell 7°. The corrections for the flow of heat *into* the water, were made by the same method, using the heat losses as determined experimentally for heat flowing *out of* the water and although the correc-

tions applied footed up 0°·676 to 0°·782, yet the corrected values agree to 0°·006, or 0·1 per cent. of the total rise.

In conclusion, we express our conviction, based on several years' work with this system of corrections, that they enable the experimenter to measure the heat brought into his calorimeter with an accuracy equal to the precision with which he can read his thermometer; that is to say, the errors in the corrections will be within the possible errors of reading the thermometer. In the case of our calorimeters, the Baudin thermometers are graduated in fiftieths of a degree, and we estimate the quarter-hundredths. (although these are not certain) yet the various corrected readings usually check up within one-half an hundredth of their mean value, and often within the quarter hundredth.

It has also been found by experience that our students readily master the method of using the system and enjoy the satisfaction of obtaining accurate and satisfactory results in this rather difficult experimental field.

METALLURGICAL LABORATORY,
LEHIGH UNIVERSITY, May 23, 1901.

TECHNICAL BREVITIES.

—In a British patent issued to Herr Kugel, of Berlin, is described a method of *depositing nickel electrolytically* in layers of such thickness that the product is equivalent to rolled nickel in its mechanical properties of toughness, durability and ductility. The method is to acidify the nickel solution with a mineral acid which is unalterable by the electric current. Such an addition usually spoils the bath, causing the deposit to flake off, but this difficulty is overcome by keeping the electrolyte at a temperature over 30 degrees centigrade. Under these circumstances a homogeneous non-crystalline metal is said to be deposited and may be put down in sheets of any required thickness.

—An Austrian patent granted to Herr C. Kellner, of Vienna, is claimed to disclose a process whereby extraordinary light-efficiency is secured with *incandescent lamp filaments*. The filament may be made by two methods. In the first, the thread is made, under great pressure, of the powder of an infusible metal such as thorium, which is then oxidized superficially by making it the anode in an oxidizing electrolyte bath. It is stated that the layer of oxide adheres strongly to the metal. The second method is to form the threads from metallic oxides which have the property of becoming incandes-

cent at comparatively low temperaturers and using as a cementing material the least possible amount of cellulose dissolved in chloride of zinc. Upon the p ssage of the current it is stated to become very compact, resembling graphite.

——The Germans have invented *a new description of glassware*, specimens of which have been on exhibition in England. This cloisonné glass, as it is called, is similar to stained glass, but is claimed to be superior. The design is prepared in double brass wires, and the interstices are filled with small pieces of colored glass. This design is then mounted upon a large sheet of plain glass, to which it is firmly attached by means of a translucent cement. Another similar sheet of glass is then placed upon the top of the design in the same way, so that the colored glass is inserted between two sheets of glass. By this means the cloisonné glass is smooth on either side. It cannot be bent or loosened, and in view of the thinness of the brass wires more light is admitted than is the case with stained glass, owing to the thickness of the leaden framework in the latter.

——Messrs. Walsh Brothers, of Janvier, N. J., have successfully reproduced the celebrated *aventurine glass*, heretofore made exclusively in Venice. They have also devised a method whereby the product can be formed into large masses of any desired form, thus adapting it for use in decorative work such as tiling, panelling, table-tops, mantlepieces, inlaid work, etc. A superb collection of specimens of this new product was made at one of the recent meetings of the Franklin Institute.

——*Celluloid* has heretofore been manufactured by dissolving nitrocellulose in camphor—that is to say, forming a mixture of nitrocellulose, camphor and alcohol. But there are other ways of mixing it. According to a publication of the Société Générale pour la fabrication des matières plastiques de Paris, celluloid can be made by using naphthalene instead of camphor. The celluloid thus produced, the paper adds, is just as good as, if not better than that in which camphor forms one of the ingredients.

——The state of California has appropriated $250,000 to purchase and preserve the grove of *redwoods* near Santa Cruz. This excellent work was accomplished largely through the agency of a body of Californians especially organized for the purpose, called the Sempervirens Society. The area purchased is unfortunately not very large, and the finest redwoods are found further north. Several thousand acres of land will be purchased in the neighborhood of Humboldt Bay, running from the ocean back across the summit of the coast range. Two or three millions of dollars would be sufficient to make the entire purchase, and the Government would do well to preserve this wonderful collection of forest trees for all time. W.

Mechanical and Engineering Section.

Stated Meeting, held Thursday, March 14, 1901.

THE AUTOMATIC GUN AND ITS MILITARY ASPECTS.

By Cecil Hamelin Taylor.

(*Concluded from p. 12.*)

Existing examples of automatic guns may be divided into two main types:

(1) Those operated by the energy of recoil, and,

(2) Those in which the gases of explosion act to operate the mechanism in any other way than to produce recoil.

Type 1 may again be divided into three classes, according to their cycles of operation.

A. In which the action opens during recoil, and closes during counter-recoil.

B. In which during the recoil, nothing is done but storing energy, which is used to return the barrel to battery, and thereby to open the action and subsequently to close it.

C. In which the energy of recoil is stored during recoil and used to return the barrel, the mechanism opening fully as the barrel reaches the half-way position; and closing as the barrel gets fully home.

The cycle of class *A*, invented by H. S. Maxim, seems to offer greater possibilities than those of either class *B* or class *C*. All else being equal it can be made to operate more rapidly, with fewer parts and more positively, than can examples of the other two classes, and it lacks but one feature possessed by either of the others; namely, tardy extraction.

The importance of tardy extraction has been magnified by those interested in guns possessing the feature, but from my own experience, I believe it negligible for any arm smaller than the three-pounder, and I attach little weight to it. The claim has been made that the cartridge-case,

being in contact with the gases of explosion, becomes so much expanded by heat that it is difficult to extract until somewhat cooled; and that the metal wall being thin and in contact with the cooler metal of the barrel, it loses sufficient heat in a small fraction of a second to greatly decrease the difficulty of extraction.

In small arm practice this theoretical advantage is negligible. The most widely known example of class *A* is the commercial Maxim machine gun. The construction and operation of this gun is roughly, as follows:

A toggle-joint connects the breech-block to the recoiling frame which carries the barrel, in such a way that the straightening of the toggle closes and locks the breech. The rear link of the toggle is an arm of a bell-crank, so designed, that after a certain distance has been travelled by the barrel and frame in its recoil, the other arm of the crank is rotated by striking a stationary abutment. The toggle is thus bent and the breech unlocked and opened. A single spring is placed so as to resist both the recoiling motion of the frame and the opening motion of the breech, and this spring returns the two pieces independently of each other. The feed may be described as a vertically sliding cartridge clip carried by the block, and it acts as extractor, face-plate and ejector also. In the firing position it is in its uppermost position, and the top engages the head of the cartridge in the belt, which is fed through the gun just over the chamber. At its lower end it engages the head of the case in the chamber. During the opening of the breech the feed remains in the same vertical position, but slides to the rear with the block, extracting one cartridge from the belt and the other from the chamber. At the full-open position the feeder drops down, bringing the live cartridge opposite the chamber and the empty case opposite the ejector opening, below the chamber. The block then advances, inserting the cartridges in their respective cavities. At the end of the closing motion the feeder is quickly moved vertically upward to engage another cartridge in the belt, during which movement it retains its grip on the case in the chamber, but drops the fired case in the

ejector opening. The lock mechanism is in no way original and deserves no notice.

In but few examples of class *A* do we find incorporated the feature which it is possible to obtain in its best form in this class of arm only, and which should therefore be one of the strongest features of arms of this class. I refer to the advantage to be obtained by connecting the block to the barrel by rigid double acting mechanism, that is, mechanism acting to move the block positively by a movement in either direction of the barrel. In the Maxim and the Borchardt this condition is one-half fulfilled by single-action connectors, giving us the advantage of increased energy for extraction, but little for insertion.

The class *B* or "Counter-Recoil" gun was first patented in 1891 by R. M. Catlin, an American mining engineer. It presents the sole advantage of allowing a longer time between explosion and extraction for the case to cool and contract, facilitating extraction. This is counter-balanced by the fact that the available energy for starting extraction is less than in the class *A* arm, owing to the slow speed and small energy of movement of the barrel at the start of the counter-recoil when the extraction takes place. This energy of movement and the tension of the recoil spring are the only forces available for extraction. As above stated, the advantage of time for cooling before extraction is of little importance in small arms, and for ordnance, high speed is of such paramount importance that this time cannot be allowed.

The inherent disadvantages of the class are slowness, weak operation, and the necessity of using some form of catch. It is possible this last objection may be eliminated from these guns, but until this is done, the presence of a catch is objectionable. This is principally owing to the practical difficulties of manufacture, tempering, etc., and to the irregular results of rust and dirt on the action of the catch. A spring is also usually necessary to operate it. During a wide experience with guns of this type I have had more difficulty with the catch than with all other parts of the gun together.

No examples of class *B* have been put on the market, but a number have been constructed. The Catlin-Carr gun has, I believe, been acquired by the Driggs-Seabury Gun and Ammunition Company, and F. M. Garland of New Haven has constructed a number of models of various calibers,—so far with but small success. The rate of fire is only about one-half that of similar guns of the previous class.

Class *C* was first patented in 1894, by Armand Meig, a German inventor. It cannot compete with class *A* in speed, but it is faster than the Catlin cycle. The principal disadvantage is the excessive speed of the breech parts, unless the counter-recoil movement of the barrel be checked. If this be done, energy is wasted, and the rate of fire diminished. The strains on the mechanism are great and partake of the nature of blows, thus requiring heavier mechanism, or reducing its life. A form of catch is common to this class, as well as the former.

We now come to type 2, in which the gas pressure acts to operate the mechanism without recoiling the barrel. This type may be subdivided into the following classes:

D. In which the fermeture is supported elastically so as to be moved by the breech-pressure on its face.

E. In which the barrel is allowed to move forward away from a stationary breech, by the friction of the ball in the bore, etc.

F. In which the gas acts in various ways after exhausting from the muzzle.

G. In which a vent leads the gases under pressure from the bore behind the projectile to the point of mechanical application.

Class *D* I term the "Piston-block" variety. It was first patented in England in 1854, by Henry Bessemer.

In order to store sufficient energy in the moving parts it is necessary that the movement of the block under pressure be greater than a certain minimum, and it has been found with this minimum that the cases were very frequently burst and the piece jammed. This results from the following action: At the instant of explosion the case is expanded tightly against the chamber walls, and at the same time

driven backwards against the fermeture. If this support be elastic it gives, and allows the head of the case to move rearwardly under the pressure. The walls of the case being pressed against the chamber-wall by many tons pressure cannot move to the rear, and the head tears itself loose from the case body which remains in the chamber as a lining, preventing the introduction of a new cartridge.

To eliminate the difficulty Maxim designed a case with ring-corrugations near the head, which were intended to give sufficient stretch to the case to allow of the heads moving to the rear without tearing the metal. This method has not given satisfaction, and even had it done so, the necessity of using a special ammunition is a grave objection to the arm for rifle caliber use. Baron von Mannlicher has also worked in this direction, but with little encouragement. The most successful example is the "Browning" pistol made in Belgium.

In spite of the grave practical objections against this class of arm, it is theoretically the most rapid in its operation, owing to the lightness of the moving parts and to the absence of lost movements. Practically, however, the necessary resistance to motion of the fermeture must be obtained either by giving it great weight and bulk, as does Maxim, or by depending upon friction, as does Mannlicher. The last method gives more irregular results, and has failed entirely.

Class *E*, in which the barrel moves forward by the friction of the shot in the bore, and the pressure of the powder gas against the front of chamber, was first patented in this country in 1892 by Raphael Mallén. The advantages of the system are those of compactness and simplicity, and for this reason various modifications have been patented in the form of pistols by Burgess, Mannlicher, Wesson and others, the Mannlicher weapon having been produced commercially.

The class may be considered as merely a modification of class *D*, in which, in order to add weight to the movable piston-block, the latter has been made integral with the stock. This will illustrate the most serious fault of the design—that of excessive recoil—for the grip or stock is

really the recoiling piece, which being lighter that the whole gun recoils more violently than would the gun if rigidly constructed, as is the modern hand repeater. One of the primary advantages of the recoil automatic systems is that of reducing the recoil by distributing the shock over a period of time. Guns of class *E*, on the other hand, not only fail to reduce recoil, but actually greatly increase it. The fault of premature extraction, simultaneous with the combustion, is common to this class, as well as the former, though the probability of failure is somewhat reduced, owing to the lesser distance travelled under pressure by the heavier breech-piece. The increase in recoil peculiar to this class gives little promise of its future efficiency.

Under class *F* must be placed the many devices designed to utilize the gases of exhaust to operate the mechanism of the piece. There are two general methods for doing this: By utilizing the impact of the gas stream and by utilizing the expensive force of the escaping gas. The difference may be said to be that between the action of steam in a turbine and in a piston cylinder.

The impact devices may be again divided into direct acting or inducing, depending upon whether the gas-jet acts directly against the mechanism or acts by inducing a partial vacuum or air current, which operates the action.

Indirect or inducing impact devices should be advantageous from the consideration of the erosive effect of the heated products of explosion in the direct-acting type, but the loss of energy involved in its transfer to the induced currents is a serious drawback. A combination of the two methods seems to promise well, since the induced current can be mixed with the gas-jet and thus cool it and at the same time increase its volume and lower its velocity, increasing the convertible energy and decreasing erosive effect.

The expansion method theoretically gives the best results, but it has to contend with the practical difficulties of making gas-tight joints which will not foul by powder-residue or allow erosion to interfere with its workings. The absence of these objections gives the impact devices a de-

cided advantage over those operated by expansion. The muzzle-exhaust system seems to be little suited to small-arm conditions, but for machine guns and quick-firing artillery it promises well. Extreme clumsiness and slight inaccuracy, due to the confined exhaust, are the chief weaknesses of the existing examples of the class among which may be mentioned McClean's and Maxim's inventions.

Class G, in which the gases escape from the barrel through a vent and act partially before the projectile has left the bore, has much in common with the last type. It may be divided into the same sub-divisions and the same general mechanisms may be employed to utilize the gas energy, whether the exhaust be from the muzzle or through a vent. The disadvantages are the same, except that the inaccuracy is reduced, though it is still somewhat disturbed by the presence of the vent and the irregularities of pressure arising from it.

The best known examples of this class are the Colt guns, used in the U. S. Navy, and the Hotchkiss, which is still in a more or less experimental state.

The Colt gun operates by the gases acting against a plug carried by a swinging lever or pendulum. Sufficient energy is imparted to the pendulum to cause it to swing through an arc of about 180° against a spring tension which operates to swing it home again. During the swing rearwardly the action is opened, and during the forward return home the action is closed and locked. The method of mounting the piston on a lever to reduce friction is excellent in itself, but the transverse forces resulting from the violent swinging and pounding of the pendulum and the reaction of the operating gases is very disturbing to the aim, and is a serious defect. Were the pendulums mounted in pairs symmetrically, much of this would be avoided and the arm greatly improved. Difficulty of feeding out of the belt has been experienced in this arm, but this is entirely due to defective detail, and though vital, yet should be easily remedied and does not come within our scope of investigation.

The Hotchkiss gun is fundamentally a single-acting

steam engine in which a spring serves to return the stroke, and where the bullet in the bore is the admission valve. Though simple in construction, it is heavy and easily clogged. The prestige of the company, whose name it bears, may suffice to make it more or less successful, but past tests have not shown it to be highly efficient, and but little can be done to improve it.

I conclude from all the above that the best examples of the automatic gun will be of the recoil class *A*, and that this is true for all sizes of arms, from the pistol to the quick-firing gun. Next to this I place the exhaust operated class *F*, after which the vent operated class *G*, then in the order named classes *C*, *B*, *E* and *D*, and it is in this order in which I expect to find them fifteen years from now, when the automatic gun will have emerged from the experimental state.

THE BALLISTIC PROPERTIES of automatic arms for military purposes are equal in importance to structural considerations of the mechanism.

The fundamental problem of service of the automatic gun on land, is that of the ammunition supply. With a rifle calibre machine gun firing continuously at the rate of about 600 shots per minute, the weight of ammunition consumed in one minute's firing is about thirty-five pounds, whence the importance of keeping the weight of ammunition as low per unit of effect as possible. The problem for the designer thus reduces itself to finding the minimum limit of power which the gun should have and to obtaining the minimum weight cartridge to give this power. To solve this question it is necessary to understand the tactical value and meaning of the automatic gun in warfare.

The advantages for military use of an automatic repeating shoulder arm, with combination magazine and belt feed, over the present magazine hand repeater are manifold. Foremost among these is that of rapidity with accuracy. The limit of semi-aimed rapidity of fire is about a shot a second with the best of the modern repeaters, though the action can be operated at about double this rate. The diffi-

culty lies, then, not so much in operating quickly, as in regaining aim after the recoil and the disturbance necessary for operation. The most efficient automatic arm must be one in which the recoil effect upon the shooter will be reduced to a minimum, and in which the mechanical moments of the operating mechanism will be exerted in a longitudinal direction. Having a given weight of weapon, we can thus either increase the ballistic energy or decrease the recoil, or, to a less extent, do both. Having the cartridge given, the arm may be lightened and the recoil reduced. This might be effected more simply in the hand repeater by the use of a spring recoil check, without making the piece automatic; but except for the general value of reducing recoil for single shots, it would add little to the value of the arm as a repeater, since with the necessity of executing the operating motions before the next shot, the recoil of the first shot has little effect on the aim of the second. In the automatic arm, on the other hand, the only disturbing effect on the second shot is entirely due to the recoil from the first. By minimizing this recoil we obtain the maximum efficiency both as a repeater and as a single shot arm.

It is true that the problem of ammunition supply is so difficult that it becomes important not only to be able to prevent more rapid firing than is now possible, but frequently even to compel slower fire. It is a generally accepted opinion that during the greater part of an action the rate of fire should not exceed four shots per man per minute. It appears, however, from experiment that doubling the rate of fire increases the effect in a given time by about one and one-half times, and on this the accepted values of fire-rates are based. Metcalfe gives the following table of rates of fire with a magazine gun and their effects;

Rate.	Shots per minute.	Effect.
"Common,"	6	1·0
"Rapid,"	12	1·5
"Magazine,"	24	2·25

It is the opinion of every civilian and military rifleman without exception with whom I have discussed the matter,

that this slow rise in effect of rapid fire is due to the disturbing influence on the aim and attention of the motions required to reload the arm, and that with the automatic system an effect of about 9·0 in the above scale could readily be obtained firing at the rate of sixty shots per minute with a belt feed, with which no leading motions need be executed by the shooter. Not only do I agree with this general conclusion, but I believe that with a skilled operator the *efficiency* will *rise* as the rate of fire increases after a certain point is passed. I believe this will result from the effect on the morale and from the results of the fire being made more apparent to the operator, allowing him to more quickly and accurately adjust for range. Particularly will this rise be noticeable in shooting from the prone positions, while from the standing positions a slight drop in efficiency may be expected.

Neglecting the above conclusions entirely, as lacking practical proof, I conclude from *accepted values* that the automatic arm must supersede the hand repeater by virtue of the fact that the rate of fire can be much more than doubled with it, or the effect in a given time can be increased to over 3·38, as against 2·25 for the magazine arm. This alone is sufficient to make its introduction certain. Objectors may argue the difficulty of controlling fire, and the rarity of the demand for the highest rate of fire, as it was argued against the magazine arm ten years ago, but so long as *concentration of effort* remains the chief factor on the battlefield, the answer will be that fire *must* be controlled; but controlled or not, the arm allowing the greatest concentration of fire in respect to time, as well as space, all else being equal, will be the most efficient arm. The problem will then be that of supply, and, generally speaking, the army having the most perfect mechanism for ammunition transport and distribution will be the victor.

Apart from this cardinal advantage of the automatic type, it presents that of allowing of better concealment, no motions which might betray the shooters' presence being required for operation. In the hands of exceptionally skilled men and fitted with telescope sights, it would make a most for-

midable weapon for picking off the enemy's officers whenever exposed, as well as for quickly plotting ranges in advance of artillery.

In describing the fire effect of crank machine guns—the prototype of the automatic gun—at Alexandria, in 1882, Lord Beresford said that, in his opinion, "machine guns, if properly handled, would decide the fate of a campaign, and would be equally useful ashore or afloat."

Prof. W. L. Cathcart, in a recent article, says:

"The place of the machine gun in the attack seems still undetermined. It is unquestionably an aid to infantry in close fighting, since, under such escort, a constant fire can be maintained. Again, in high-angle firing a hail-storm of bullets can be rained upon the heads of men behind entrenchments. Its effectiveness in defense, however, is beyond a doubt. Nothing can equal it in stopping the rush of desperate men, or in reinforcing the fire of infantry. The place of the arm, therefore, is essentially in the reserve as a gun of position."

Capt. Henry Metcalfe, in his "Ordnance and Gunnery," the text-book used at West Point, says: "Owing to the desire to simplify the supply of ammunition machine guns are frequently fitted to the cartridge used by infantry. * * * Their ballistic properties restrict their scope to the zone of infantry fire, within which their value consists in the small number of men required for their service and the consequent possibility of selecting the coolest and most skillful men and of protecting them from the enemy's fire. The difficulties of transportation on land appear to assign this class to the defense, for which service the concentration of its fire upon objects hidden by their own smoke renders it most valuable. * * * Compared with ordinary field artillery the range and power of the infantry ammunition is so limited, the correction of the aim so difficult, the moral effect of solid projectiles so small, that machine guns of small caliber, though rendered popular by their great mechanical efficiency, will probably in service be relegated to subordinate purposes of the defense, and for use against an enemy unprovided with artillery.

"When compared with infantry operating in open or wooded ground their deficient mobility would often render them an obstruction rather than a help; since only under exceptional circumstances can they maintain their own defense.

"Owing to the suddenness with which, in order to produce a decisive effect, their services are required it has been proposed to attach them to small tactical units of infantry and cavalry; but the objections above cited and the evident difficulty of administrating such scattered commands would probably cause this plan to fail. * * *

"The transport of the large amount of ammunition that machine guns require compels the use of wheeled draught (except in mountain service) and therefore assigns them to the artillery. The question then arises, whether, having a given supply of men, horses and money, these means may not better be utilized in the legitimate sphere of the artillery, rather than in providing a defensive arm of only occasional utility. * * * For naval purposes, where difficulties of supply hardly exist, their value is greater."

We see that the rifle caliber machine gun as constructed until now is deficient in mobility and in vulnerability compared to infantry, and deficient in range and shock, compared to artillery. It is superior to infantry in accuracy and concentration of fire, and to artillery in mobility. Our effort, then, must be directed toward increasing these advantages and minimizing these unfavorable features.

The first question—that of mobility—includes the considerations of portability, mobility proper, and the ease and speed with which the piece on the march may be put in readiness to fire.

There are two mountings for machine guns—the tripod or stand mount, and the wheeled carriage. With the first the piece must be carried bodily when changing position, while in the second it is drawn. A minimum total weight for gun and stand of about 35 pounds has been imposed upon the tripod mounting by the necessity for steadiness in overcoming recoil.

In these mounts a saddle is attached to one leg of the

tripod, upon which the operator sits, thus adding a fraction of his own weight to that of the piece. By a tripod, on the fore legs of which the operator might rest his feet while sitting on the rear leg, the operator's entire weight would be applied at a more efficient center of effort than in the former case. By this means the restrictions as to minimum weight, imposed by recoil, may be entirely eliminated, and the lightest piece becomes the most efficient. A water jacket has very generally been applied to this type of arm, under the impression that long-continued firing would frequently be required. With a heavy weapon mounted on the wheel carriage, and thus having but slight mobility, continued fire will doubtless be required, as the gun will not be used from a precarious or temporary position, but will be reserved for use at more or less protected semi-permanent points where continued fire will be demanded. With a weapon, however, weighing say 15 pounds complete with stand, adapted to be handled by one man and used either as a shoulder arm or on its tripod, and to be set up, from the packed position, on its tripod to begin firing within 15 seconds of the word of command, and as quickly repacked, continuous fire for over 100 shots would seldom be required. With the modern infantry ammunition, a barrel without a water jacket may be fired 600 times within the minute without serious injury to the bore, so that in exceptional circumstances automatic continuous fire could be maintained for a considerable period with such a gun.

At the point where a piece ceases to become easily portable and operable by one man, it becomes, in fact, artillery, and at once loses its mobility to a great extent. Thus a gun weighing 15 pounds could be handled in the skirmish line, if so desired, but a 40-pound gun would be of little use there, and would be but slightly more mobile than one weighing 140 pounds. If, therefore, we wish to construct a gun much heavier than the infantry rifle, for continuous fire, with a water jacket, and elevating and traversing mechanism which has been found most important for such work, the gun will be mounted most efficiently for military purposes, on a wheeled carriage. Once mounted on wheels,

slight additions of weight are no longer vitally objectionable. The arm may, therefore, be more freely adapted to the various functions it may be called upon to perform.

The ballistic demands of such a gun are these: The effective range should exceed by at least 1500 yards that of the infantry arm against which it may be used; the ball should be of sufficient weight to inflict severe wounds on horses when high angle fire is used; the penetration should be at least one and one-half times that of the infantry arm, in order to force the enemy to throw up heavier entrenchments, or to reach him behind those of standard profile and to drive him from the face of wooded ground. This penetration would be ample to pierce at moderate ranges, the $\frac{1}{8}$ and $\frac{1}{4}$-inch plates at present used to protect the personnel of machine guns, and would thus necessitate the use of heavier armor, decreasing the enemy's mobility. The complete piece should be composed of not over four, easily separable elements, of a maximum individual weight of 40 pounds, so that it could be used as a mountain gun, and if necessary carried by men.

These considerations, together with those of minimum weight of gun and ammunition, can best be combined in a gun of about caliber ·38-inch, firing a mantled bullet of about 500 grains weight, with a velocity of about 2500 feet second. The gun body would weigh between 30 and 40 pounds, the trail and wheels each about the same. The ammunition would weigh about nine rounds to the pound, so that 300 rounds could be carried by one man. If a shield were added it would be in two pieces, each weighing less than 40 pounds, though for mountain service it would seldom be required.

It will be seen that such a gun has an almost limitless sphere of utility. It can be used in the attack at ranges at which only artillery can be brought against it and its mobility is such that it may avoid to a great extent the effects of artillery fire. The power of the arm would be sufficient to greatly facilitate picking up ranges, as the effect of impact will be much more readily detected than that of infantry ammunition. It may be possible even to construct

a special non-explosive range-finding shot to indicate the point of impact still more clearly. As a light mountain gun, ground is accessible to it to which no other weapon than the infantry rifle could be brought, and from such a position high angle or direct fire simulating with its 500 shots per minute, the effect of shrapnel could be maintained to a radius of 5,000 yards. This function would be equally valuable whether in the attack or defence. Even as a high angle gun on level ground, it could deliver its fire at a distance safe from infantry fire interference.

For naval-landing purposes such a gun is ideal, being of a size easily handled from a launch and of sufficient range to clear a landing without danger from infantry fire to the personnel. The penetration, speed and flatness of trajectory make it a formidable weapon, even against torpedo boats, though for this purpose it will, undoubtedly, be found inferior to the full caliber gun.

Full-caliber automatic guns, unlike the smaller sizes, cannot do double service. Naval conditions demand flat trajectory, penetration and rapidity of fire more forcibly than they demand large mine power or great range, whereas army conditions reverse these requirements. First comes range and mine-power, and then in the order named, rapidity of fire, penetration, and trajectory. The mobility of field guns gives rise to the problem of checking any movement of the carriage due to the recoil.

Considering these conditions carefully, I conclude that for naval use a gun of about caliber 1.25 inch, firing one-pounder shot containing about 200 grains bursting charge with a velocity of about 3,000 feet seconds would give the best results. This gun would give a trajectory so flat that within the range of about 1,500 yards no change of sight would be required to keep on a target the size of a torpedo boat, bow on. This question of uniform elevation within critical ranges is a vital consideration for torpedo-boat destroying guns, and sufficient weight does not yet seem to have been given it. The penetration would be ample to completely pierce any torpedo destroyer even with forward transverse bunker protection, yet built; while the mine-

powder is just sufficient to cause fragmentation. The rate of fire could be over 300 shots per minute. The mounting should have accurate worm elevating mechanism not adapted to be thrown out of register, and coarser mechanical traverse which can be thrown in and out quickly to allow of freely swinging the piece when necessary to quickly change the aim. A shield of at least ¼ inch thickness should be carried on the mount as a protection against machine gun fire. This gun would alternate well with a semi-automatic six or nine pounder. I think it doubtful that guns heavier than the three-pounder will be made purely automatic.

For army service the conditions call for a gun of about caliber 1.56 inch, throwing a long shell, somewhat tapered at both ends, weighing about three pounds, and containing about a 1,000 grains bursting charge, with about 2,000 feet seconds velocity. Such an arm would be as small and light as possible, consistent with a range nearly equal to that of field artillery, mine-powder sufficient to be effective against houses and light field fortifications, and the use of an effective canister. The fact that for a given weight of discharge per minute small canister is more effective than large against troops at critical ranges, owing to the possibility of its more perfect distribution, makes such a gun more nearly self-protecting than field artillery proper. It should be mounted on a mountain high-angle-fire carriage, and, if expected to be exposed to infantry fire, a shield should be applied. Mechanical elevating and traversing mechanism, which can readily be thrown out of gear, should be fitted.

My conclusions on the requirements of automatic guns lead me to believe that some such system as the following will be ultimately adopted by the great armaments of the world.

The infantry rifle will be a recoil automatic of class *A*, weighing only about 6½ pounds, and designed to be operated as a single loader, magazine gun and belt feeder. A simple method of attaching to a tripod weighing not over 5 pounds will be provided, the gun being used either from the shoulder or stand as desired. The arrangement will be such that the

arm complete may be carried in a compact holster, with the tripod if required, and be capable of being set up and fired within ten or fifteen seconds from the command, and as quickly repacked. The present infantry ammunition, with slightly increased power, will be retained. This arm will also replace the cavalry carbine.

The small caliber machine gun will use a cartridge of about caliber ·38 on the general lines of the infantry ammunition. This arm will have a water jacket or other cooling device, and will be mounted on a wheeled carriage, with or without a shield. It will be made in various constructions, but the recoil types (those of class *A* and classes *F* and *G*) will be most successful. The arm will be handled as a unit, as well as in battery, and attached to small tactical units of infantry and cavalry, as were the "batallion guns" in the Seven Years' War. In the navy it will entirely displace the rifle caliber machine gun.

The present one pounder "pom-pom" will be generally superseded in the army by a similar gun of over double its weight, of about four times its power, and without a water jacket. This arm will be handled as a special type of artillery, and will be of wide tactical value. The general data of this piece will be about as follows;

Maximum weight of single element	250 pounds.
Weight of gun body	250 "
Weight of carriage complete	350 "
Total weight without shield	600 "
Weight of one round	4·5 "
Weight of projectiles	3 "
Muzzle velocity	2,000 feet second.
Bursting charge	1,000 grains.

In the navy we shall see a high-powered, water cooled one pounder displace the present inefficient light gun, and become one of the considerable factors in naval actions. The data of this gun will be:

Weight of gun body	200 pounds.
Weight of complete piece (with mounting) . .	350 "
Weight of one round	1·7 "
Weight of projectile	1· "
Muzzle velocity	3,000 feet second.

The light one pounder automatic may be retained for naval landing and other special services, but will play a subordinate rôle.

The feasibility of making guns of 6 pounds and above to operate fully automatically, is a question which cannot now be decided. It remains to be seen just what examples of the automatic and semi-automatic types will do, what the rate of fire will be, and what the various advantages and disadvantages of each type are. I am inclined to the belief that though the fully automatic larger guns will ultimately supersede those operated manually in any way, yet the immediate future will see the semi-automatic type generally adopted.

The next important step in ordnance, after the development above outlined has taken place, will be in the direction of improving the ballistics of the arms by reducing the weight of ammunition to perhaps less than one-half its present weight. This problem is one for the chemist as well as for the mechanician, and its solution will mean another great advance.

A NEW PHONOGRAPH.

A new type of phonograph, the invention of a Danish engineer, Valdemar Poulsen, was shown at the Paris Exposition. It works upon an entirely new principle, and the record, instead of being made of wax by a stylus, is made upon a steel wire by the action of a magnet. A cylinder is wound full of steel wire about one millimeter thick, the wires touching each other. In front, in a position analogous to that of the stylus, is a small electromagnet whose polar ends are brought out and are reduced to a small diameter to embrace the upper half of the steel wire. It is supported upon a horizontal rod, and the lateral motion obtained by a guide which travels between the wires. The magnet is connected with a telephone transmitter and battery, and the sound waves cause a variation in intensity of the electromagnet, and this in turn acts upon the steel wire passing before it, leaving a permanent impression. When the action is reversed, the wire reacts upon the magnet and the sound is heard in the telephone. The magnetic trace may be obliterated by passing a continuous current in the electromagnet and turning the cylinder. The apparatus was shown in the Danish exhibit; another form was shown, in which the record is made upon a thin steel band wound upon a drum.

CHEMICAL SECTION.

Stated Meeting, held Thursday, March 28, 1901.

SOME ABRIDGMENTS IN CHEMICAL CALCULATIONS.

BY PROF. JOSEPH W. RICHARDS,
Member of the Institute.

In calculating the volumes of gases produced from any weight of solid, liquid or gaseous substance, a few simple relations render the calculations very direct.

The molecular formula of a gas represents in an equation one volume, relatively, of that gas. The molecular weight represents, likewise, a relative weight. If, now, we call the total relative weights entering into a given reaction kilograms, then each molecule of gas represented in the equation will represent the volume of molecular weight in kilos of a gas, which, by Avogadro's law, is the same for all gases. For hydrogen this volume is

$$\frac{2}{0{\cdot}09} = 22{\cdot}22$$

cubic meters, and this is the volume of molecular weight in kilos of all gases. We can, therefore, say that, calling the relative weights entering into an equation kilograms, each molecule of gas in the equation represents 22.22 cubic meters of that gas.

By similar reasoning and calculation we can affirm the relations between the relative weights considered as grams, pounds or ounces, and the actual volumes thus represented in liters, cubic feet or cubic inches. We therefore have the following relations:

If relative weights be	Each molecule of gas is
Kilos	22·22 cubic meters.
Grams	22·22 liters.
Pounds	355·9 cubic feet.
Ounces	22·24 cubic feet.

(Volumes being at 0° C. and 760 millimeters.)

E. g.:

In the manufacture of acetylene gas

Molecules of gas = relative volumes	I		I		I		I	
	CaC_2	+	H_2O	=	C_2H_2	+	CaO	
Relative weights	64	+	18	=	26	+	56	

Whence it follows that

64 kilos	of CaC_2	+ 18 kilos	of H^2O	produce	22·22 m^3	of	C^2H^2
64 grams	" "	+ 18 grams	" "	"	22·22 liters	of	"
64 pounds	" "	+ 18 pounds	" "	"	355·9 ft^3	of	"
64 ounces	" "	+ 18 ounces	" "	"	22·24 ft^3	of	"

The most complicated of chemical equations bear the application of these simple principles in a similar manner.

To calculate quickly from the volume composition of a gas the weight of carbon, hydrogen or oxygen which it will contain in unit of volume, we need only to apply the following principles:

Equal volumes of all gases contain equal numbers of molecules; therefore, if a gas molecule of any gas whatever contains one atom of carbon, or of hydrogen, or of oxygen, we can say of such gases that equal volumes of them contain equal numbers of atoms of carbon, hydrogen or oxygen, as the case may be, and, therefore, equal weights of each of those elements respectively.

But 1 cubic meter of CO contains 0·54 kilos of carbon; therefore, that statement is true of 1 cubic meter of any other gas with one atom of carbon in its molecule, such as CO_2, CH_4, etc. Gases with two atoms of carbon in their molecule, as C^2H^6, would contain $2 \times 0{\cdot}54 = 1{\cdot}08$ kilos of carbon by the same principles, and so on to C_3H_8, etc. Carbonic oxide, CO, also contains 0·72 kilos of oxygen per cubic meter; whence a similar set of relations for CO_2, etc. Hydrogen gas, H_2, contains 0·09 kilos of hydrogen per cubic meter, whence it follows that 1 cubic meter of a gas with one atom of hydrogen in its molecule, as HCl, will contain

$$\frac{0{\cdot}09}{2} = 0{\cdot}045$$

kilos of hydrogen.

We can, therefore, state that for a gas containing in its molecular formula one atom of carbon, hydrogen or oxygen, the weights of those elements present in a given unit of volumes would be:

	Carbon.	Hydrogen.	Oxygen.
In 1 cubic meter	0·54 kilos.	0·045 kilos.	0·72 kilos.
" 1 liter	0·54 grams.	0·045 grams.	0·72 grams.
" 1 cubic foot	0·54 ounces.	0·045 ounces.	0·72 ounces.
" 1 " "	0·0337 pounds.	0·00281 pounds.	0·045 pounds.

For a gas with two atoms of carbon, hydrogen or oxygen in its molecule, the respective weights are twice the above; and so on for any gas, no matter now complicated. For practical calculations, I recommend keeping only the above constants in mind, and simply doubling or trebling the volume of the gas, instead of doubling or tripling the constant.

E. g.: Calculate the weight of carbon, hydrogen and oxygen present in 1 cubic meter and 1 cubic foot of natural gas, of the following composition;

	PER CENT. (BY VOLUME).		
CO_2	5·7	=	0·057
C_2H_4	0·9	=	0·009
CO	15·4	=	0·154
H_4	8·3	=	0·083
CH_2	3·8	=	0·038
N_2	65·9	=	0·659
	100·0		1·000

CALCULATION FOR CARBON.

CO_2	=	0·057
C_2H_4 . . . . 0·009 × 2	=	0·018
CO	=	0·154
CH_4	=	0·038

0·267 × 0·54 = 0·1442 kilos per m³

0·267 × 0·0337 = 0·0090 pounds per ft³

CALCULATION FOR HYDROGEN.

C_2H_4 . . . . 0·009 × 4	=	0·036
H_2 . . . . . . 0·083 × 2	=	0·166
CH_4 . . . . . 0·038 × 4	=	0·152

0·354 × 0·045 = 0·01593 kilos per m³

0·354 × 0·00281 = 0·0010 pounds per ft³

CALCULATION FOR OXYGEN.

CO_2	0·057 × 2 =	0·114
CO	=	0.154
		0·268 × 0·72 = 0·1930 kilos per m^3
		0·268 × 0·045 = 0·01206 pounds per ft^3

These principles save much labor, especially in metallurgical calculations.

METALLURGICAL LABORATORY
LEHIGH UNIVERSITY, March 1, 1901.

THE ANDREW CARNEGIE RESEARCH SCHOLARSHIP.

We have received from the Secretary of the Iron and Steel Institute of Great Britain the accompanying information, issued by order of the Council of the Institute, relating to the foundation of a scholarship by Mr. Andrew Carnegie for the purpose of fostering the progress of iron and steel metallurgy by aiding the cause of original research in this branch of applied science:

"A Research Scholaship or Scholarships, of such value as may appear expedient to the Council of the Iron and Steel Institute from time to time, founded by Mr. Andrew Carnegie, Vice-President, who has presented to the Iron and Steel Institute thirty-two one-thousand dollar Pittsburgh, Bessemer and Lake Erie Railroad Company 5 per cent. Debenture Bonds for the purpose, will be awarded annually, irrespective of sex or nationality, on the recommendation of the Council of the Institute. Candidates, who must be under 35 years of age, must apply, on a special form before the end of April to the Secretary of the Institute.

"The object of this scheme of Scholarships is not to facilitate ordinary collegiate studies, but to enable students, who have passed through a college curriculum or have been trained in industrial establishments, to conduct researches in the metallurgy of iron and steel and allied subjects, with the view of aiding its advance or its application to industry. The National Physical Laboratory, on the governing body of which the Iron and Steel Institute is represented, would for many reasons be a very suitable place in which such a research could be carried out. There is, however, no restriction as to the place of research which may be selected, whether university, technical school, or works, provided it be properly equipped for the prosecution of metallurgical investigations.

"The appointment to a Scholarship shall be for one year, but the Council may at their discretion renew the Scholarship for a further period instead of proceeding to a new election. The results of the research shall be communicated to the Iron and Steel Institute in the form of a paper to be submitted to the Annual General Meeting of members, and if the Council consider the paper to be of sufficient merit, the Andrew Carnegie Gold Medal shall be awarded to its author. Should the paper in any year not be of sufficient merit, the medal will not be awarded in that year."

Further information and application blanks may be obtained by interested parties on application to Mr. Bennett H. Brough, Secretary, 28 Victoria Street, London, Eng. W.

CHEMICAL SECTION.

Stated Meeting, held Thursday, March 28, 1901.

THE CHEMISTRY OF DEPOSITS IN STEAM BOILERS.

BY W. E. RIDENOUR,
Member of the Institute.

This is a very old subject, having been worked upon by many eminent chemists on both sides of the Atlantic, and from many different views.

Some have devoted their ideas to the prevention of scale formation inside the boiler, under which heading you will find in literature and on the market at the present time as many remedies as there are patent medicines for the ailments of the human body.

Others have taken up the purification of water outside the boiler; while again others have debated as to the chemical salts existing in these deposits. With this latter subject I wish to deal this evening, in conjunction with a study of their physical appearance.

Before proceeding with these deposits, I wish to call attention to the vast amount that accumulates in a boiler from a good water for steam purposes in a month's run.

An average of several analyses of a water which is largely used in Philadelphia, the Schuylkill, is as follows (when it is clear):

	Grains Per U.S. Gallon.
Organic and volatile	5·060
Calcium sulphate	3·560
Magnesium sulphate	·602
Sodium chloride	1·167
Calcium carbonate	·357
Solids	10·746

There are 4·519 grains of scale-forming matter per gallon in this water, which, for a 1,000 horse-power plant, the average for these times, and allowing 4 gallons to be evaporated per hour per horse-power, will give the following:

4	gallons per hour per horse-power.
10	hours per day.
40	gallons per day per horse-power.
26	days per month.
1,040	gallons per month per horse-power.
1,000	horse-power.
1,040,000	gallons per month per 1,000 horse-power.
4·519	grains per gallon of scale-forming matter.
4,699 760	grains.
671	pounds of sediment per month.

The above are small figures for the average plant, as private wells are generally used, which are much worse, ranging from twenty-five to seventy-five grains per gallon; in one case in particular I recall from the soft coal district of this State, it amounted to eighty-three grains per gallon, and so situated that it had to be used.

Small wonder, then, that so many workers have been attracted to this troublesome subject.

For convenience, I have divided these accumulations into four classes, according to the predominating constituent:

(1) The calcium sulphate scales.
(2) The calcium carbonate scales.
(3) The silicate scales.
(4) The magnesia scales.

The calcium scales are, as a class, very hard and porcelain-like, examples Nos. 7 and 9, but a few are quite soft, example No. 8. They can generally be told from the others with the aid of a simple magnifier, by their glassy or vitreous appearance.

There has been some debate as to how the calcium sul phate exists, whether as a hydrate or an anhydrite.

Mr. V. B. Lewes (*Chemical News*, 1899, 59–222) states that it is first deposited as a hydrate $(CaSO_4)_2H_2O$, by coming in contact with the heated plates forms the anhydrite $CaSO_4$. I have always found it to occur as the anhydrite, $CaSO_4$, example No. 7, from South Australia:

	Per Cent.
Moisture at 100° C.	·23
Calcium sulphate	94·89
Magnesium hydrate	1·98
Silica	·25
Organic and undetermined	2·65

The calcium carbonate deposits are usually moderately soft, but the presence of even small quantities of either magnesia, calcium sulphate or silica modifies them to variable degrees of hardness, some equaling those of the first class.

Example of soft scale No. 10.

Example of hard scale No. 11.

If moderately pure they are readily recognized by the magnifier, being composed of distinct crystals, samples Nos. 10 and 15; some being easily seen by the naked eye, sample Nos. 12 and 14. This crystalline appearance is pronounced in some deposits of but 50 per cent. calcium carbonate, sample No. 14, which contains:

	Per Cent.
Calcium carbonate	51·73
Calcium sulphate	26·10
Magnesium hydrate	11·32
Silica	·42
Iron oxide and alumina	·39
Organic and undetermined	10·04

The silicate scales to me are the most strange and interesting. They are most common in the Southern States, but I have received a few from different States.

In these scales there is a combination of calcium oxide and silica, existing as calcium silicate, which, I think, is formed during the violent boiling under pressure in the boiler, by the free silicic acid, occurring in the water, reacting with the calcium carbonate.

Sample No. 2, from Louisiana:

	Per Cent.	Calcium Silicate.
Calcium carbonate	36·40	
Calcium oxide	7·32	7·32
Silica	41·00	7·84
Magnesium hydrate	.50	
Alumina	9·68	15·16
Organic and undetermined	5·10	

Sample No. 3, from New Jersey.

	Per Cent.	Calcium Silicate.
Moisture at 100° C.	4·55	
Calcium carbonate	7·47	
Magnesium hydrate	2·74	
Calcium oxide	21·94	21·54
Silica	51·07	23·50
		45·04
Calcium sulphate	1·56	
Iron oxide	1·34	
Organic and undetermined	9·33	

An extreme case is sample No. 4 from Olympia, Washington:

	Per Cent.	Calcium Silicate.
Calcium oxide	36·42	36·42
Silica	40·51	39·02
		75·44
Magnesium hydrate	3·04	
Iron oxide and alumina	2·66	
Oil	11·50	
Organic and undetermined	5·87	

Sample No. 16 from this State is especially interesting, as I was able also to get a sample of the water. The scale contained:

	Per Cent.	Calcium Silicate.
Calcium oxide	5·42	5·42
Silica	48·02	5·80
		11·22
Calcium sulphate	3·95	
Magnesium hydrate	3·58	
Iron oxide and alumina	27·08	
Organic and undetermined	11·95	

The water analyzed:

	Grains Per U. S. Gallon.
Calcium carbonate	1·311
Calcium sulphate	·104
Magnesium carbonate	1·147
Sodium chloride	·850
Silica	1·469
Organic and volatile	1·340
Solids	6·221

In comparing these two analyses, it is seen that the calcium carbonate occurring naturally in the water has completely disappeared before forming into scale, making quite possible the hypothesis that the silica has reacted with the calcium carbonate during evaporation.

The silicate scales have no characteristic physical appearance.

The magnesia scales have caused considerable disagreement among the many investigators, as to which salt of magnesium is found in these deposits, whether magnesium oxide, magnesium hydrate, or magnesium carbonate. Magnesium hydrate is now the generally accepted combination and I agree that this is the usual salt occurring.

Sample No. 5 from Texas contained:

	Per Cent.
Calcium carbonate	4·25
Calcium sulphate	7·50
Magnesium hydrate	82·95
Silica	3·10
Iron oxide and alumina	1·18
Organic and undetermined	1·02

But a few specimens have been examined by me, which contained magnesium carbonate.

Sample No. 17 from Pennsylvania.

	Per Cent.
Calcium oxide	4·39
Magnesia	59·79
Carbonic acid	22·29
Silica	5·36
Alumina	2·92
Organic and undetermined	5·25

which is equivalent to

	Per Cent.
Calcium Carbonate	7·83
Magnesia	38·23
Magnesium carbonate $(Mg.\ Co_3)_4\ Mg\ (OH)_2$	42·25
Silica	5·36
Alumina	2·92
Organic and undetermined	3·41

It is quite possible that magnesium carbonate is first deposited from the water upon being heated, but changes

after forming into scale, in proportion to the heat to which it is exposed, into magnesium hydrate, or even magnesium oxide.

There are no marked characteristics under the glass to distinguish these deposits from the others.

It is not safe to express an opinion of a water supply, by an analysis of the usual sample of deposit taken from a steam boiler, as exclusive of the influence on the scale of the various preventives used, different portions of the same boiler form scales of quite different composition.

Samples No. 12 and 13 are from the same boiler, but are as different as if formed by a carbonate and a sulphate water.

Sample No. 12 contains 96 per cent. of calcium carbonate, while No. 13 has 76 per cent. of calcium sulphate.

This can be explained if we consider the location in the boiler from which the two samples were taken.

Scale No. 12, composed chiefly of calcium carbonate, came from near the feed-pipe, where the water first comes in contact with the heat, thereby driving off the free carbonic acid and precipitating the calcium carbonate thus held in solution; while the calcium sulphate still remains dissolved until it reaches the hottest part of the boiler, the bottom plate, where sample No. 13 collected. Mr. V. B. Lewes mentions that he examined several scales from different parts of the same boiler, all of which varied considerably.

I only wish further to call your attention to a few curious deposits on the table.

LABORATORY G. W. LORD,
PHILADELPHIA, March 28, 1901.

ESTIMATION OF HYDRATE IN THE PRESENCE OF ALKALI CARBONATE.

By W. E. Ridenour,
Member of the Institute.

After reviewing the several methods of estimating caustic alkali in the presence of carbonate, and carbonate in the presence of hydrate, the method proposed by R. T. Thompson appeared to be the best, if accurate.

Mr. Thompson (Sutton, Vol. Anal., Fifth Edition), weighs off a quantity of the sample to be tested, dissolves in water and titrates with standard acid, using phenolphtaline, which gives the hydrate and half of the carbonate; then, by adding methyl orange and continuing the titration, the other half of the carbonate can be found.

To test the above method, a solution of sodium carbonate C.P. was made and titrated with following results:

Sod. Carbonate Solution.	Normal Hydrochloric Acid.	Indicator.
10 c.c.	9·535	Methyl orange.
10 c.c	4·574	Phenolphtaline.
	4·985	Methyl orange.
20 c.c.	9·149	Phenolphtaline.
	9·971	Methyl orange.
	Decinormal Hydrochloric Acid.	
10 c.c.	94·78	Methyl orange.
10 c.c.	45·026	Phenolphtaline.
	49·858	Methyl orange.

Standard acid, with the factor 1·6377, was used, the sodium carbonate solution was well diluted, and the end of the burette kept below the surface of the liquid.

The indicators (U.S.P., 1890) were also tested; four drops in 100 cubic centimeters of distilled water responded at once to one drop of normal acid and alkali.

A solution of sodium hydrate, C.P., was then made and tested in the same manner.

Sod. Hydrate Solution.	Normal Hydrochloric Acid.	Indicator.
10 c.c.	1 .·822	Methyl orange.
10 c.c.	11·565	Phenolphtaline.
10 c.c.	·257	Methyl orange.
	11·565	Phenolphtaline.
	Decinormal Hydrochloric Acid.	
10 c.c.	2·67	Methyl orange.
	115·444	Phenolphtaline.

The above would seem to indicate the presence of carbonate in the hydrate, so barium chloride solution (W. Smith, *J. S. C. I.*, i., 85), was added to 100 cubic centimeters of sodium hydrate solution in a flask until it ceased to give a precipitate,* water added to make 200 cubic centimeters allowed to settle and the clear liquor titrated.

Clear Sodium Hydrate Solution.	Decinormal Hydrochloric Acid.	Indicator.
20 c.c.	2·57	Methyl orange.
	115.464	Phenolphtaline.

If carbonate was present then it is impossible to eliminate the same by precipitation with barium chloride solution.

Combining sodium carbonate and sodium hydrate solutions in various proportions, the following results by titration were obtained.

By comparing the different results it can be seen that phenolphtaline does not indicate half of the carbonate, either alone or in combination with hydrate, but a definite ratio is observed between the results in the titration of pure

* Produced only a slight cloudiness.

Sodium Hydrate Solution.	Sodium Carbonate Solution.	Normal Hydrochloric Acid.	Indicator.
10 c.c.	10 c.c.	16·088	Phenolphtaline.
		5·191	Methyl orange.
10 c.c.	10 c.c.	21·2796	Methyl orange.
10 c.c.	1 c.c.	11·9762	Phenolphtaline.
		·7196	Methyl orange.
10 c.c.	3 c.c.	12·9528	Phenolphtaline.
		1·6962	Methyl orange.
		Decinormal Hydrochloric Acid.	
1 c.c.	1 c.c.	15·98	Phenolphtaline.
		5·60	Methyl orange.

NOTE.—Allowance must be made in proving these results by the factor 104.5726, for the possible presence of carbonate in the sodium hydrate used.

sodium carbonate when using methyl orange alone, and using phenolphtaline followed by methyl orange.

Multiply by two the number of cubic centimeters of normal hydrochloric acid necessary to neutralize a definite quantity of pure sodium carbonate indicated by methyl orange, using phenolphtaline, then methyl orange and divide by the number of cubic centimeters of normal hydrochloric acid necessary to neutralize the same quantity of pure sodium carbonate, using methyl orange only, gives 104·5726, *i. e.*,

$$\frac{2 \times 4{\cdot}985}{9{\cdot}535} = 104{\cdot}5726$$

For figures see Table I.

Therefore, to obtain the number of cubic centimeters of normal acid corresponding to the carbonate present in a mixture of alkaline hydrate and carbonate, multiply by two the number of cubic centimeters of normal acid indicated by methyl orange, using phenolphtaline, then methyl orange and divide by the factor 104·5726.

LABORATORY OF GEO. W. LORD,
PHILADELPHIA, March 28, 1901.

VICTORIUM, A NEW ELEMENT.

Sir William Crookes has recently given an account to the Royal Society of his discovery of the new element which he calls victorium. It has a pale brown color and dissolves easily in acids. Its oxide is less basic than that of yttrium, but more so than the greater part of the earths of the terbium group. The chemical properties of victorium differ in many respects from those of yttrium, but generally speaking it may be said to occupy an intermediate position between this element and terbium. It is admitted that the oxide of victorium has the formula Ve^2O^3, its atomic weight is not far from 117. The photograph of the spectrum given by the oxide shows certain definite lines which have not been observed with any other body. The spectrum is obtained by the incandescence of the body in a vacuum tube; the light given off has been analyzed by a spectroscope of great precision and the exposure upon a photographic plate shows a series of interesting rays in the ultra-violet region. In order to examine the negative an apparatus has been constructed which will measure to the 1-100,000 inch. W.

ACTION OF RADIO-ACTIVE MATTER IN A MAGNETIC FIELD.

The *Scientific American* gives the following abstract of a communication lately presented to the French Academy by M. Becquerel giving the results of some recent experiments on the behavior of radio active matter in a magnetic field, viz.:

In the experiments previously described, the active matter contained a large proportion of the newly discovered element radium; in continuing his experiments with matter containing the other new element, polonium, discovered by M. and Madame Curie, which possesses properties analogous to the former, he finds that the action is entirely different; the radiations from this body, while showing in other respects nearly the same activity as those of radium. are not appreciably affected by the magnetic field. M. Becquerel shows this conclusively in the following experiment. The preparation of polonium is placed between the poles of an electro-magnet whose intensity equals 4,000, then 10,000 c. g. s. units; above this, at distances varying from 2 to 10 millimeters, a photographic plate was disposed horizontally. This plate was not enveloped in black paper, as in the case of radium, as the rays from this body are absorbed to a considerable degree; the operation was therefore carried out in the dark. Under these conditions, after some minutes' exposure an impression is obtained upon the plate which is symmetrical with relation to the radiant source, and this impression is the same, whether the magnet is excited or not. If the preparation of radium is then substituted under the same conditions, an impression is obtained upon the plate which, under the influence of the magnetic field, is thrown over to one side as in the previous experiments. It thus appears that the radiations emitted by polonium are not influenced in the same manner as those of radium. It has been observed also that these rays are very unequally absorbed by different substances. To these observations should be added those made by M. and Mme. Curie upon the compounds of uranium, which are found to be unaffected by the magnetic field. W.

CHEMICAL SECTION.

Stated Meeting, held Thursday, May 23, 1901.

MOISSAN'S RESEARCHES ON FLUORINE AND THE FLUORINE COMPOUNDS.

BY DR. H. F. KELLER,
Member of the Institute.

The student of the history of any science is constantly impressed with the great lack of symmetry in the progress of that science at the different periods of its development.

He observes that the great majority of those, who, working simultaneously, contribute to our knowledge, direct their energies toward one common goal marked out for them by certain great leaders of thought.

In chemistry, for instance, we have a number of fairly well-defined periods which derive their names from those lines of research which predominated in them. We speak of periods of pneumatic, quantitative, organic and physical chemistry, and such terms characterize quite well the main directions of chemical work during the times to which they refer.

A single province of a science may be thus explored, while others are entirely neglected.

Some of us remember the time when the current literature of our science consisted almost exclusively of organic research work, while a younger generation of chemists has witnessed the rise of another school which seeks to apply mathematical and physical methods to the solution of chemical problems, and our journals now fairly teem with publications along these lines. Where only yesterday we had heated controversies on structural formulæ, condensations, carbocyclic and heterocyclic compounds, and spacial arrangement of atoms, the words ionization, conductivity, phase rule, and the like strike our ear to-day.

But the more careful student of scientific progress cannot fail to notice also that there has always been a smaller

band of workers who, isolated from the main body, have pursued untrodden paths and among them men of genius who have enriched their science with veritable bonanzas of important discoveries.

Such pathfinders and explorers have lived in all the periods of our science, and the present generation, notwithstanding what we are told in eloquent memorial addresses, has no cause to lament them as an extinct species, so long as we can point to such men among us as Berthelot, Emil Fischer, Baeyer, Van't Hoff, Ramsay and Moissan.

And the investigations of the two last named afford ample proof that the inorganic province of our science, far from being exhausted, presents a most encouraging prospect of rich yields to come. As Moissan has so well said: "No subject is ever closed. It remains always open for our successors; we can only add a link to an infinite chain."

The subject I wish to bring before you this evening, gentlemen, are the researches of this contemporary chemist upon fluorine and the fluorine compounds.

Historical.—The process of etching on glass by means of a mixture of fluorspar and sulphuric acid, was practised more than two centuries ago by Schwankhard of Nuremberg, but the first chemical investigation of the reaction of the acid with calcium fluoride was made by Margraff, in 1768. The active product of this reaction remained unknown, however, until the year 1771, when Scheele obtained and described hydrofluoric acid, and also showed that it has a corrosive action upon glass. The Swedish chemist did not succeed in preparing hydrofluoric acid in the pure state and its preparation and properties were made the subject of study by many other chemists. The most complete investigation was made by Gay-Lussac and Thenard, in 1809. In 1813 and 1814 Sir Humphry Davy published a number of important papers on hydrofluoric acid and the fluorides, in which he showed that the acid does not contain oxygen, and that it must be regarded as an hydracid consisting of hydrogen and an unknown element, fluorine, an hypothesis which, it appears, had been suggested to him by Ampère.

To test the correctness of this view, Davy prepared the fluoride of ammonium by neutralizing pure hydrofluoric acid with pure ammonia, and strongly heated the product in a platinum still. Not a trace of moisture appeared in the cooler parts of the apparatus, while the ammonium salt was sublimed. Submitted to the same conditions the oxygen acids invariably furnished considerable quantities of water. In order to obtain more positive proof of the hypothesis, Davy endeavored to isolate from hydrofluoric acid the radical which he believed to be combined with hydrogen and to have properties similar to those of chlorine. His numerous attempts in this direction remained fruitless; neither by means of powerful electric currents, nor by the chemical action of chlorine on hydrofluoric acid and various fluorides was it possible to produce the desired effect. Davy concluded that fluorine is endowed with more energetic affinities than any other known element, but expressed the belief that the element might be isolated under conditions which he had not been able to bring about.

Although the experience of Gay-Lussac and Thenard, as well as Davy's, had demonstrated that anhydrous hydrofluoric acid is one of the most dangerous substances to experiment with, not a few chemists, after them, took up the problem of isolating fluorine from it. In their heroic attempts to solve the problem, some of these experimenters suffered severely, and Louyet even paid with his life for his devotion to science.

A great deal of valuable knowledge concerning the fluorine compounds was accumulated in this way, especially by the work of Fremy and Gore, but the preparation of the element in the free state had not been achieved in 1884, when Moissan began those beautiful experimental researches of which it is my desire to give you a brief acccount.

(1) *Various Attempts to Isolate Fluorine.*—After carefully studying the extended literature on the subject, Moissan tried in four different ways to effect the isolation of fluorine. On three of them he met with no success, but the fourth led him triumphantly to his goal.

These attempts comprise experiments on:

(*a*) The action of the electric-spark discharge upon certain gaseous fluorides, such as those of silicon, phosphorus, arsenic and boron.

(*b*) The action of incandescent platinum upon the fluorides of phosphorus, and the fluoride of silicon.

(*c*) The electrolysis of arsenic trifluoride, and

(*d*) The electrolysis of hydrofluoric acid.

Considerable space is alotted in Moissan's book to the description and discussion of the numerous and varied experiments by which the first three methods were put to test, but, although they brought to light many new and interesting facts, we may dismiss them with the author's

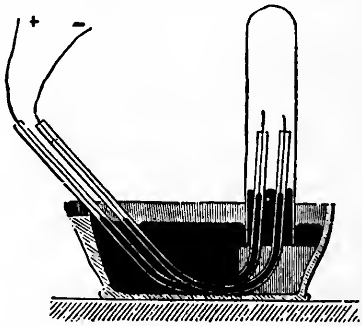

FIG. 1.—Apparatus employed in submitting silicon fluoride to the action of the induction spark. The dry gas is collected over mercury in a glass vessel and sparks are passed between the terminals of the platinum wires which are surrounded by the curved glass tubes containing mercury. No indication of any decomposition was observed even when the sparking was long continued.

words concluding that part: "These studies did not give me free fluorine, but furnished invaluable information on the electrolysis of liquid fluorine compounds; they trained me in this delicate mode of experimenting, and finally led me to the decomposition of anhydrous hydrofluoric acid."

(*Figs. 1, 2* and *3* illustrate the apparatus used in these experiments.)

The apparatus used for the electrolysis of arsenic fluoride was not adapted to that of hydrofluoric acid. The latter consisting of two gaseous elements, it was essential to separate these the moment they were set free. A U-shaped

platinum tube was therefore used, the ends of which were closed with cork stoppers soaked in paraffin which held and insulated the platinum rods serving as electrodes. Just beneath each stopper a small branch tube was attached to the limbs of the U-tube, to permit the gaseous products to escape from the vessel. To prevent volatilization of the hydrofluoric acid (it boils at 19·5°), the apparatus was immersed in a bath of methyl chloride. This liquid boils

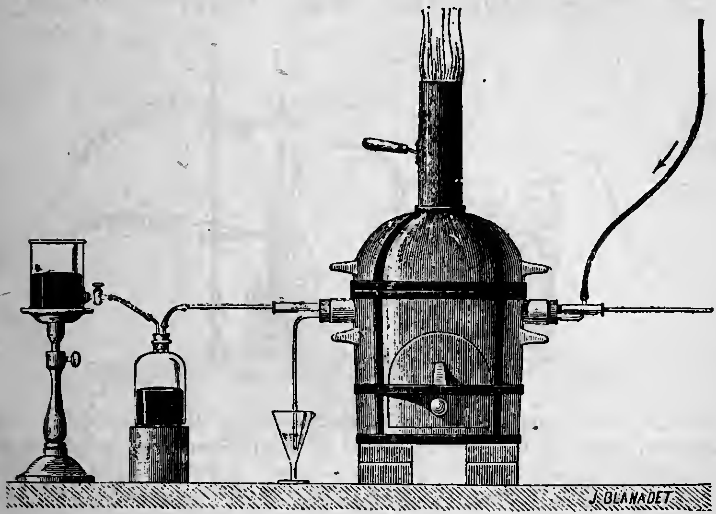

FIG. 2.—Apparatus for studying the action of red-hot platinum on the fluorides of phosphorus and silicon. The metal was used in the form of carefully purified "sponge" and placed in a platinum tube, which passed through a porcelain tube so as to permit enclosing the heated part in an atmosphere of nitrogen gas. The air in the inner tube is then displaced by hydrogen, and this in turn by nitrogen, while the tube is being heated. Finally the gaseous fluoride contained over mercury in the bottle is conducted into the tube as shown in this cut. Although these experiments were variously modified, they only showed that it is useless to attempt isolating fluorine in this way.

at — 23° and can be made to produce temperatures as low as — 50°, by forcing a rapid current of dry air through it.

The first experiments made with this apparatus showed that every trace of moisture must be excluded from the acid, and confirmed also the experience of Faraday and Gore, that the anhydrous acid does not conduct the electric current.

This latter difficulty was easily removed by the addition of acid potassium fluoride, which readily dissolves in the acid and makes it a conductor.

When current was passed through the solution of the potassium salt in the anhydrous acid, bubbles of gas were disengaged at both electrodes. The current continued to flow, and the evolution of gas was quite regular. The gas generated at the negative pole was recognized as pure hydrogen, the gas at the positive pole acted powerfully on the

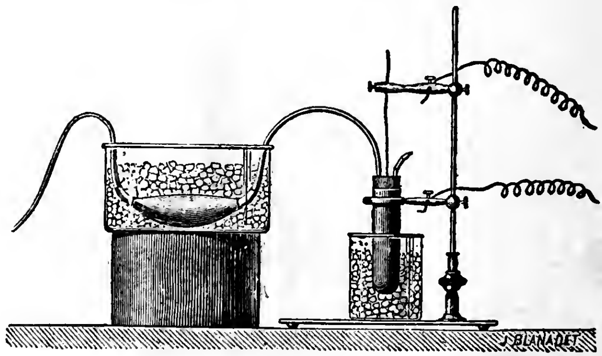

FIG. 3.—The apparatus used in the electrolysis of the fluoride of arsenic consisted of a platinum test-tube, closed by a paraffined cork which carried two platinum delivery tubes. One of these, bent at a right angle, permitted displacing the air in the tube by nitrogen gas, while the other was connected with a platinum receiver, surrounded by cracked ice, in order to condense the fumes of the fluoride. As the cut shows, the tube formed the negative electrode and a wire passing through the stopper served as the anode. The apparatus having been cooled, pure arsenic fluoride was introduced in the tube, the air then displaced by nitrogen and a current from 70 to 90 Bunsen cells passed through the liquid. The separation of arsenic indicated that decomposition occurred, but *no gas* was liberated. Moissan believes that pentafluoride of arsenic was first produced, and this again reacted with the arsenic formed at the same time, the tri-fluoride being regenerated.

platinum electrode, charred the cork, and gave other indications that it might be fluorine.

Before this gas could be collected and studied, however, many obstacles, partly in the construction of the apparatus and partly in the method of working, had to be cleared away.

The apparatus was finally given the form shown in *Fig. 4*. The limbs of the U-shaped tube are closed with care-

fully fitted fluorspar stoppers, through which pass in their axial directions the platinum electrodes.

A lateral delivery tube is attached to each limb of the main tube to permit the escape of the gases. The U-tube is mounted in the lid of the jar containing methyl chloride.

The electric current is derived from a battery of Bunsen elements. It is impossible here to give all the numerous and minute details which it was found necessary to observe in the operation of this apparatus. They are fully described in Moissan's book.

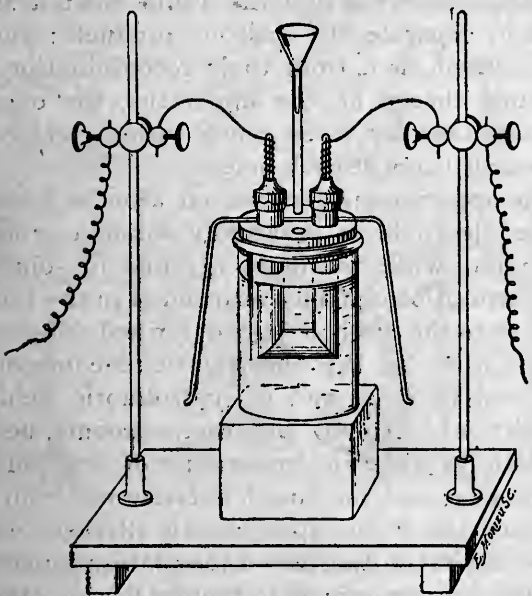

FIG. 4.

The *modus operandi* is briefly this: The hydrofluoric acid, freshly prepared, is introduced in a perfectly anhydrous condition, and about one-half of its weight of absolutely dry acid potassium fluoride is added. The fluorspar stoppers are then inserted and made gas-tight. A temperature of — 23° is steadily maintained during these operations, by the evaporation of the methyl chloride surrounding the tube. The methyl chloride is replenished from time to time.

As soon as the current is made to pass through the liquid, a regular evolution of gas sets in at each pole. The hydrogen given off at the negative pole is readily identified by its burning with a non-luminous flame, giving off water vapor, and by its other well known properties. At the positive pole another gas, apparently colorless, but chemically exceedingly active, is produced.

The first successful experiment of this kind was made by Moissan on June 26, 1886.

When the electrolysis of the liquid was continued for several hours, it occurred that the liquid was not sufficient any longer to separate the gaseous products; violent detonations resulted then from their recombination. With the maximum charge of the apparatus, the experiment could be continued for three hours with a yield of about one and one-half litres at each pole.

When the apparatus is dismounted after an experiment, the positive electrode is invariably found corroded and worn to a point, while platinum is found in solution and also in the form of black flakes suspended in the liquid.

In addition to the method just described, Moissan tried to obtain fluorine by the electrolytic decomposition of potassium acid fluoride, and of hydrofluoric acid, under various conditions. Among other experiments, he electrolyzed hydrofluoric acid at a temperature of $+ 15°$ in a vessel made of fluorspar, and the fused potassium salt in vessels of platinum as well as fluorspar, but in all these cases the action of the liberated fluorine on the platinum parts of the apparatus was so energetic as to rapidly destroy them and render the apparatus useless.

Since fluorine had never been isolated before Moissan succeeded in decomposing hydrofluoric acid by the electric current, it remained for him to furnish proof that the gas liberated at the positive pole really *was* the free element. Its physical and chemical properties, which will be fully described farther on, were found to exactly agree with those which the close analogy of the fluorine compounds with those of chlorine had suggested, but various other hypotheses as to the possible nature of the gas presented

themselves. The gas certainly *was* endowed with wonderful chemical activity; but was it not possible to account for that by the presence of nitric acid, chlorine, ozone, or, perhaps a compound of fluorine with hydrogen richer in fluorine than hydrofluoric acid?

All these assumptions were submitted to the test of experiment and proved to be untenable. The manner in which the absence of hydrogen was demonstrated is of special interest. An apparatus was arranged (*Fig. 5*) which permitted passing the gas produced at the positive pole over red hot iron, and collecting any hydrogen so formed in

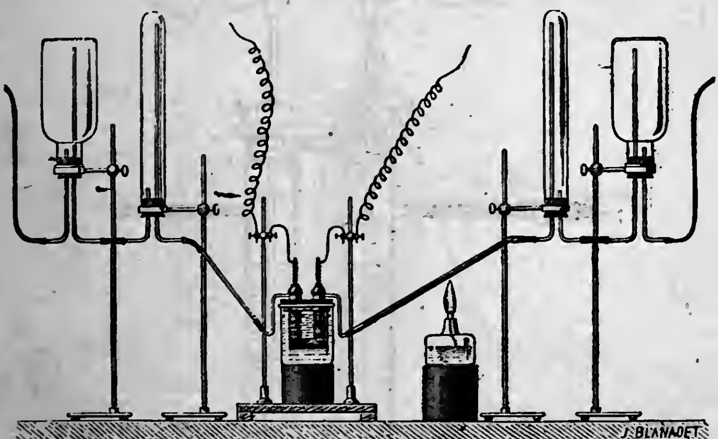

FIG. 5.

an atmosphere of carbon dioxide. The latter could then be removed with the aid of caustic potash. In the several careful experiments made with this apparatus, it was found that the carbon dioxide left only a small bubble of gas on being absorbed by caustic potash, and this residue was air and contained no hydrogen. And it was further ascertained that the increase in weight of the tube containing the iron, corresponded almost exactly to the amount of fluorine equivalent to the hydrogen collected at the negative pole during the experiment. The vapors of hydrofluoric acid were retained in a tube filled with dry potassium fluoride.

For the exact observation of the properties of fluorine, the determination of its physical constants, and the preparation of certain fluorine compounds, it was deemed advisable to procure the gas in larger quantities than the original apparatus had furnished.

Moissan states that hundreds of liters of fluorine were consumed in his researches.

A new apparatus (*Figs. 6 and 7*), of much larger dimensions than the first, was therefore constructed. Its capacity was about 160 cubic centimeters, so that it could receive at

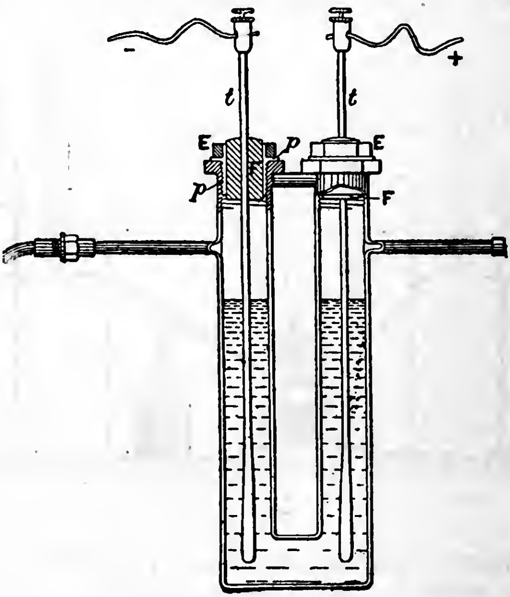

FIG. 6.

least 100 cubic centimeters of the liquid in one charge. The shape of the U-tube, too, was slightly altered, and various minor improvements introduced. The electrodes, for instance, were made of *pure* platinum, instead of the alloy of platinum and iridium, and were very thick at the ends dipping into the liquid.

The glass jar containing the methyl chloride (or other refrigerant) was placed inside another larger jar, containing pieces of calcium chloride to absorb aqueous vapor from the insulating air.

The main improvement, however, consisted in the devices for removing the hydrofluoric acid vapor from the fluorine gas. A small platinum worm condenser was attached to the delivery tube, and the temperature of this condenser was maintained at — 50°, or even lower, by the aid of a suitable refrigerant (liquid air is best adapted, though methyl chloride was used in most of the experiments). The end of the condenser is in turn connected with rather wide platinum tubes filled with pieces of sodium fluoride, a non-hygroscopic salt which retains hydrofluoric acid at the ordinary temperatures. All the joints of the

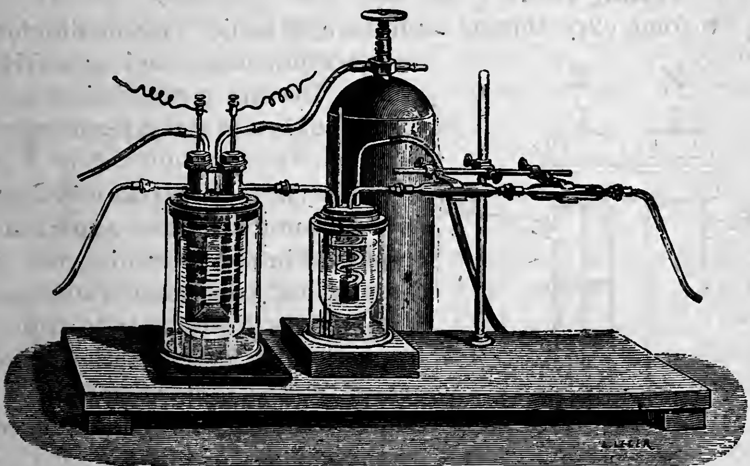

FIG. 7.

apparatus were most carefully rendered gas-tight by means of lead or compressed gold sponge. Lead is only superficially attacked by the fluorine, and gold only at higher temperatures.

The current required was generated by a battery of twenty-six to twenty-eight Bunsen cells arranged in series. This current was made to pass through an ampèremeter and a Bertin commutator.

In one instance 25 ampères and 52 volts were registered before the apparatus was placed in the circuit, and these figures were reduced to 4 ampères and 38 volts when the electrolyte was introduced.

To reduce the cost of the apparatus, and adapt it for commercial purposes (in case practical uses of fluorine should be found) a vessel made of copper (*Fig. 8*), was substituted for the platinum tube, and it was given still greater dimensions. The yield was also augmented by increasing the surface of the electrodes, which, however, had to be made of platinum, as copper was found to dissolve very quickly.

As much as five liters of fluorine per hour were obtained with this apparatus; but, despite energetic cooling, it was not found practicable to increase the current on account of its heating effect.

In some experiments a mixture of solid carbon dioxide and acetone was used as refrigerant. By this means it is possible to maintain a temperature of — 80.°

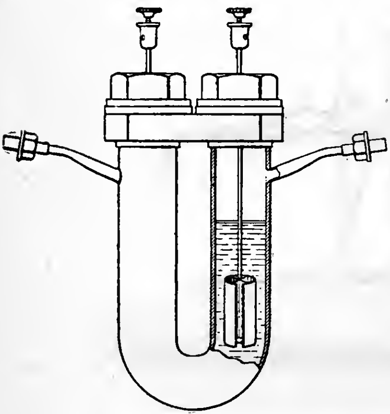

FIG. 8.

(3) *Physical Properties of Fluorine.*—Inasmuch as the apparatus employed in the determination of the physical constants of fluorine were almost entirely made of platinum, it was indispensable at the outset to ascertain the conditions under which this metal is attacked by the gas.

It was found that in the absence of hydrofluoric acid vapor, no appreciable action occurs at 100°; and that energetic combination does not set in below 400°. At about 660° platinum fluoride is very rapidly formed.

In the presence of hydrofluoric acid, fluorine has a corrosive action upon platinum even at 0°.

So thorough has been the investigation of fluorine by Moissan and his collaborators that it may be asserted without exaggeration, that the physical and chemical properties of the new element are as perfectly known as those of any of the other halogen elements.

The odor of fluorine is described as disagreable and

penetrating, recalling that of hypochlorous oxide as well as that of nitrogen peroxide. It is, however, partly masked by the odor of ozone, owing to the presence of moisture. Nevertheless the smell is sufficiently characteristic to permit the detection of even traces of free fluorine in fairly dry air. The gas is dangerous to inhale even in very small quantities, as it produces violent bronchial irritation and mucous anæsthesia lasting for several weeks.

The color of the gas is greenish-yellow, but much paler than that of chlorine. It is distinctly seen on looking through a stratum of one meter in thickness.

As was to be expected from the position of fluorine in the halogen group, its liquefaction proved to be extremely difficult. It was, however, accomplished by Moissan and Dewar, and the properties of liquid fluorine were exhaustively studied by these great masters of experimentation.

Liquefaction was effected a few degrees below the boiling point of liquid oxygen, and the boiling point of liquid fluorine was determined at — 187°. The color of this liquid is pale yellow, similar to that of the gas, but more distinct. Liquid fluorine is miscible in all proportions with both liquid air and liquid oxygen. It does not congeal when cooled to — 210°. Its density is 1·14, and its capillary constant is smaller than that of water, alcohol or liquid oxygen.

The density of fluorine gas was found to be 1·265, instead of the theoretical value of 1·316.

Spectroscopically the gas is characterized by thirteen lines in the red, having wave lengths which range between 744 and 623. The most brilliant of these lines are 677, 640·5, 634, and 623. In layers of one meter in thickness the gas presents no absorption spectrum.

(4) *The Chemical Properties of Fluorine* are more powerful than those of all the other known elements.

Thus it unites energetically with hydrogen gas, even in the dark and at temperatures as low as — 210°.

It inflames both bromine and iodine, but shows no tendency to combine with chlorine.

Sulphur, selenium and tellurium take fire spontaneously

in the gas. Sulphur yields a mixture of gaseous fluorides, while selenium and tellurium are converted into solid compounds.

Oxygen, nitrogen and argon do not appear to enter into combination with it under any conditions.

Phosphorus reacts very energetically. The main product is the pentafluoride, $P F_5$, a gas. In addition to this, Moissan has prepared two other gaseous fluorine compounds of phosphorus, the trifluoride, $P F_3$, and the oxyfluoride, $P F_3O$. All three substances were made the subjects of extended investigations by him.

Arsenic and antimony combine with fluorine at the ordinary temperatures forming the corresponding fluorides. In both cases the union is attended with incandescence.

Crystallized silicon, lamp-black and amorphous boron all take fire when projected into fluorine gas, and are converted with extreme energy into fluorides.

By this means a mixture of fluorides of carbon was obtained, of which the tetrafluoride, $C F_4$, has been specially studied. It was also prepared in several other ways. It is a gas having a density of 3·09, and is liquefied under atmospheric pressure at $-15°$. Insoluble in water, it dissolves readily in alcohol and ether. It attacks glass, especially at higher temperatures, and is readily decomposed by heating in contact with metallic sodium, and also by an alcoholic solution of caustic potash.

The action of fluorine on the metallic elements is less energetic than that on most of the non-metals, owing to the formation of solid fluorides which form protecting coats upon their surfaces.

The metals of the alkalies and alkaline earths inflame spontaneously in fluorine.

Microscopic crystals of fluorspar were obtained artificially when pure calcium metal was burned in fluorine.

Lead is but slowly transformed into the fluoride, but iron reduced by hydrogen becomes incandescent in contact with the gas.

Magnesium, aluminium, nickel and silver, upon being gently heated in fluorine, all take fire and burn in it with great brilliancy.

When manganese is exposed to a current of the gas, it is converted into a beautiful crystallized compound, having a violet color, manganic fluoride, Mn F_3. At a low red heat the latter abandons fluorine, and manganous fluoride, Mn F_2, remains.

Gold and platinum are not attacked by fluorine below a red heat, and the fluorides which result at this temperature are again resolved into their constituents at still higher temperatures. The formula of the platinum fluoride so obtained is Pt F_4.

Among the most remarkable chemical reactions of free fluorine is the decomposition of water at ordinary temperatures (*Fig. 9*). The products are hydrofluoric acid and ozone.

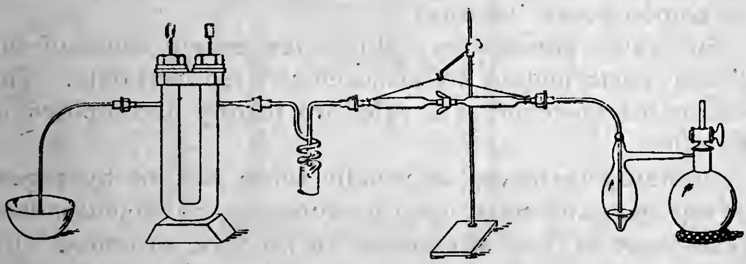

FIG. 9.—Apparatus for demonstrating the action of a large volume of fluorine upon a small quantity of water. Fluorine produced in the large copper generator (*Fig. 8*) is conducted into water contained in a small glass bulb, cooled to 0°. The gas is thence passed into a balloon, such as are used in determining the density of gases; it is a mixture of oxygen and ozone, in which the proportion of the latter may be determined by means of potassium iodide.

When the fluorine is present in considerable excess, the ozone produced is sufficiently concentrated to show its beautiful blue color. With a slight excess of water, and at a temperature of 0°, oxygen gas containing as much as 19 per cent. of ozone and entirely free from oxides of nitrogen may be obtained.

Some compounds, such as hydrogen sulphide, sulphur dioxide, hydrochloric, hydrobromic and hydriodic acids take fire in contact with fluorine.

Phosphorus trifluoride combines with it to form the pentafluoride.

The oxides of carbon do not appear to react with fluorine, but carbon disulphide as well as cyanogen are inflamed by it.

Both the metallic and non-metallic chlorides, bromides, iodides and cyanides are decomposed in the cold by fluorine gas.

The latter reacts also on a large number of metallic oxides, either in the cold, with the alkaline earths for example, or at a low red heat, as is the case with the oxides of iron, nickel, zinc, and lead.

The same is true of the sulphides.

The phosphides and arsenides are for the most part attacked at ordinary temperatures.

The carbides of lithium and the alkaline earth metals are rendered incandescent in contact with fluorine, while those of aluminum, zirconium and uranium are decomposed by it upon gentle heating.

Sulphates, phosphates and nitrates, except those of the alkaline earth metals, are attacked at a red heat only. The carbonates, however, as a rule, are readily decomposed in the cold.

Organic substances, especially those rich in hydrogen, are energetically acted upon by fluorine. So violent indeed is the reaction in most cases as to produce, attended with evolution of light and heat, the total destruction of the compound, the products being hydrofluoric acid and fluorides of carbon.

The hydrocarbons and their derivatives take fire in fluorine; the alcohols and ethers are mostly acted on in the same way.

Organic acids react less readily, especially those of complex molecular structure.

Amines and many of the alkaloids burn rapidly in fluorine, yielding volatile products.

All these reactions, however, are much too violent to lend themselves to the study of organic fluorine compounds. It was in other ways that substances suitable for this purpose were procured.

By taking advantage of the double decompositions between the fluorides of silver and zinc, on the one hand, and the iodides of various hydrocarbon radicals, on the other, Moissan succeeded (*Fig. 10*), in preparing the fluorides

of ethyl, methyl and isobutyl, and M. Meslans continuing these researches added fluoroform, acetyl fluoride, the fluohydrins of glycerol, as well as propyl, isopropyl, and allyl to the list of organic fluorine compounds.

Most of the organic fluorine compounds previously studied, belonged to the benzene series, and only few of the aliphatic derivatives mentioned had been prepared. Even these had been imperfectly studied and characterized.

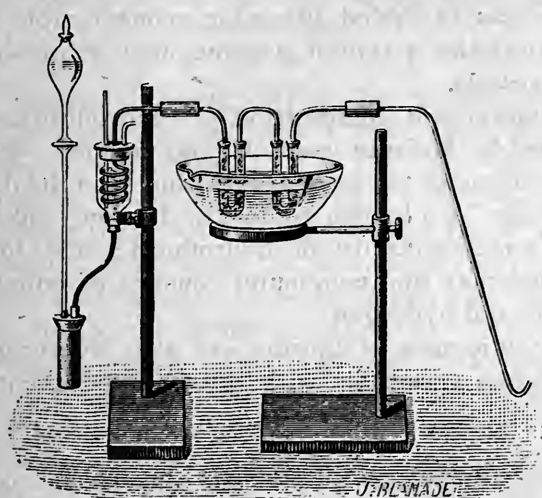

FIG. 10.—Apparatus used for preparing ethyl fluoride. This consists of a brass tube fitted with a double-perforated cork, carrying a separatory funnel and a leaden worm condenser tube. The latter is cooled to $-23°$ by the aid of methyl chloride, and connected with two U-shaped glass tubes which contain silver fluoride, and are immersed in water of $40°$. Fluoride of silver is placed in the brass vessel and ethyl iodide allowed to fall on it drop by drop from the funnel. Ethyl fluoride escapes as a gas, while fluoidide and presently iodide of silver are produced. The vapors of ethyl iodide which accompany the gas are mostly condensed in the worm and the remaining traces are removed by the silver fluoride in the U-tubes.

The results of the investigations by Moissan and Meslans on the fluorine substitution products may be summed up in the statement that they are the perfect analogues of the corresponding compounds of the other halogen elements, and that their study confirmed the position of fluorine at the head of the halogen group.

Experiments with fluorine conducted at very low tem-

peratures showed that, while its chemical energy was greatly reduced, it was still capable of reacting at temperatures as low as — 210° with hydrogen and with certain hydrocarbons, such as oil of turpentine.

The action of hydrofluoric acid and of fluorine on glass was also carefully investigated. It was found that the glass was attacked by the former at the ordinary temperature, but that fluorine acted so slowly that it was possible to preserve the gas in sealed tubes for a considerable time, and also to study the action of fluorine upon many substances in glass vessels.

The volumetric composition of hydrofluoric acid was determined by Moissan in an original manner. By measuring the volume of the oxygen resulting from the decomposition of water by a known volume of fluorine, and ascertaining the exact quantity of hydrofluoric acid formed, he established that this compound consists of equal volumes of fluorine and hydrogen.

The atomic mass of fluorine was also redetermined, and found in close agreement with former experimenters, to be 19·05.

Such, gentlemen, is a brief and imperfect account of a research which undoubtedly takes rank with the greatest masterpieces recorded in the annals of inorganic chemistry. This research was not prompted by a current theory or fad, but attacked an old problem, the solution of which required a rare combination of sagacity, perseverance, resourcefulness and, last but not least—heroism, all of which Henri Moissan has shown himself to be possessed of in an extraordinary degree. In isolating fluorine and studying its properties and its compounds, he has verified the brilliant prognostication of Ampère and Davy, and fixed the position of the element in the natural system.

HENRI MOISSAN.

Mining and Metallurgical Section.

Stated Meeting, held March 13, 1901.

SOME EFFECTS OF DEFORESTATION IN CHINA.

BY F. LYNWOOD GARRISON,
Asso. M. Am. Soc. C.E., M. Am. Inst., M.E. Professor Mining Engineering, Franklin Institute.

At the present time there is probably no large country in the world that offers so many interesting sociological problems as the Chinese Empire. It is well known to students of this science that race development and characteristics are in the main influenced and moulded by the surrounding natural physical conditions. It is doubtful if these great fundamental problems can be better illustrated and studied than in contemporary China and Chinese. It is a curious and profoundly significant fact, that approximately one-third of the human race have gone on for many hundreds of years developing a civilization peculiar to themselves, and, if we except the introduction of Buddhism, very little if at all affected by outside influence. The great nations of antiquity have arisen, flourished and crumbled into dust, whilst the Chinese have gone on the even tenor of their way, that was much the same a thousand years ago as it is to-day.

Bounded on the east, southeast and south by the sea, on the west by the jungles of Burma, Siam and the tremendous mountains of Thibet, and on the north by the deserts of Mongolia, this great country is uniquely hedged in by natural barriers not to be overcome until steam navigation made the sea an easy and safe highway for mankind. Unlike Japan, China has resisted and shrunk from the touch of modern western civilization with its wheels, cranks and hissing steam. Culminating in the present crisis, the Chinese can resist no longer. The fiat has gone forth, take your place with the other nations of the earth, lest your national existence be extinguished forever!

We have now reached a time when it will be possible to study this interesting and peculiar people, to see in what manner they have used and abused their birthright. How have they lived in and cared for this beautiful and fruitful country; have they utilized its resources in a proper manner? As yet we possess relatively very little knowledge of the interior of this huge empire, but judging from the observations so far recorded, we would say the Chinese have abused their natural resources without check or stint. We need not, for our present purpose, inquire into causes of such effects, further than is absolutely necessary in order to determine how to avoid making similar mistakes in the care and preservation of our own great and splendid fatherland.

The protestations from well informed organizations and individuals against the destruction of our forests in the United States have been so persistent and well sustained that general public interest has been now aroused to some sense of responsibility.

While it is obvious to every one that our timber resources are rapidly melting away, very few realize the dangers of this deforestation, or its effects upon the productive capacity of the country as our population becomes rapidly denser.

Droughts we have had, but famines never. Will famine be the concomitant of drought when our population numbers 400,000,000? is the natural and irresistible reflection in this connection.

If any doubts that drought, flood and famine follow deforestation as surely as night succeeds day, let him visit China and carefully study the writings of the few competent observers who have lived in and travelled through that little known country.

It is safe to say that drought, flood and famine are of annual occurrence in one or another portion of the Middle Kingdom, and that the famines are apt to be severe owing to the lack of efficient transportation from more favored sections of the Empire. It must not be assumed, however, that even a thoroughly good system of railways throughout China

would prevent famine, though undoubtedly it would check absolute starvation.

Russia, which is well provided with railways, seldom has a year without famine. Grinding poverty, filth and superstition are the common lot of the Chinese peasant and the Russian muzhik, and if there is any choice the Chinaman is probably the better off of the two. Similar causes have produced similar effects in both countries, deforestation has already ruined much of China and is beginning to spoil some sections of European Russia. There is a general tradition amongst the natives throughout the whole of the Middle Kingdom that the mountains and hillsides were once covered with forests and that the rains have decreased in frequency and increased in violence from generation to generation. In China as in some other countries the floods were formerly regular during successive years, whereas at later periods they have grown more irregular and violent. In mountainous regions torrential rains do not soak into the bare uncovered earth, the rapid run-off tears up the soil, fills the water courses and lakes with gravel and sand. Standing on the mountain tops of Eastern Shantung last summer, it was not difficult for the writer to picture in his mind those bare brown hills covered with primeval forests, the dry rocky gulleys filled with babbling brooks, and the deep valleys studded with beautiful lakes and streams now filled and choked with sand and gravel. The once deep-bayed indentations of this fine sea-girt province are deep no longer, but are now so silted that a good anchorage for deep-draft ships can only be obtained even in the best of the harbors, like Wei-hai-wei and Kiao-chau by constant dredging. The celebrated geographer and geologist Baron von Richthofen, in speaking of Shansi province, remarks "that the traveller at every step has occasion to contrast the present poverty and inertness of the inhabitants, with the signs of a previously better condition. The large cities, even villages, the temples, the remains of magnificent public structures, as well as the history of China, give evidence that the northern provinces have been in a more prosperous state." The cause, aside from politi-

cal, that led to these conditions Richthofen believes is the deterioration of the climate, which is the probable consequence of the extermination of the forests. Throughout the whole country, from Hankow to Peking the mountain and hill sides are destitute of trees and shrubs and offer a most desolate aspect. The exceptions are the groves of trees at the villages and temples and parts of the Fu-niu-shan mountains where many hillsides are planted with oak trees for feeding wild silkworms. Richthofen thinks there are no positive proofs that these conditions had formerly been otherwise, but it is exceedingly probable and the people everywhere assert that their mountains were covered with trees in old times. He further states that besides this injurious effect of the destruction of the forests upon the climate in general, there is an immense amount of deterioration incessantly going on, which would not take place if the hills were wooded. The heavy rains wash off the soil from the rocks, and the water, instead of penetrating into the earth, and being stored up for feeding springs, runs off the hillsides and descends in torrents through gulches which were before perfectly dry. In the valleys, the rivers in overflowing their banks spread much fine sand or silt over the surface of the fertile alluvial soil, thus often rendering extensive regions unfit for agriculture. Instances of this kind are, according to Richthofen, numerous in Shansi, on the borders of the great plain. If it were not for the *löss* formation, he declares that northern China would already be a desert with some fertile valleys enclosed. Even this beneficial formation, which is the principal seat of agriculture and, more than other kinds of soil, capable of storing up moisture, is undergoing a rapid destruction.*

Archibald J. Little,† in writing of Szechuen province, remarks that at the present time in China wherever there is a stream that will float a log, there are no logs to float, and he might have added that in places where timber could not be in any way transported, it is converted into charcoal.

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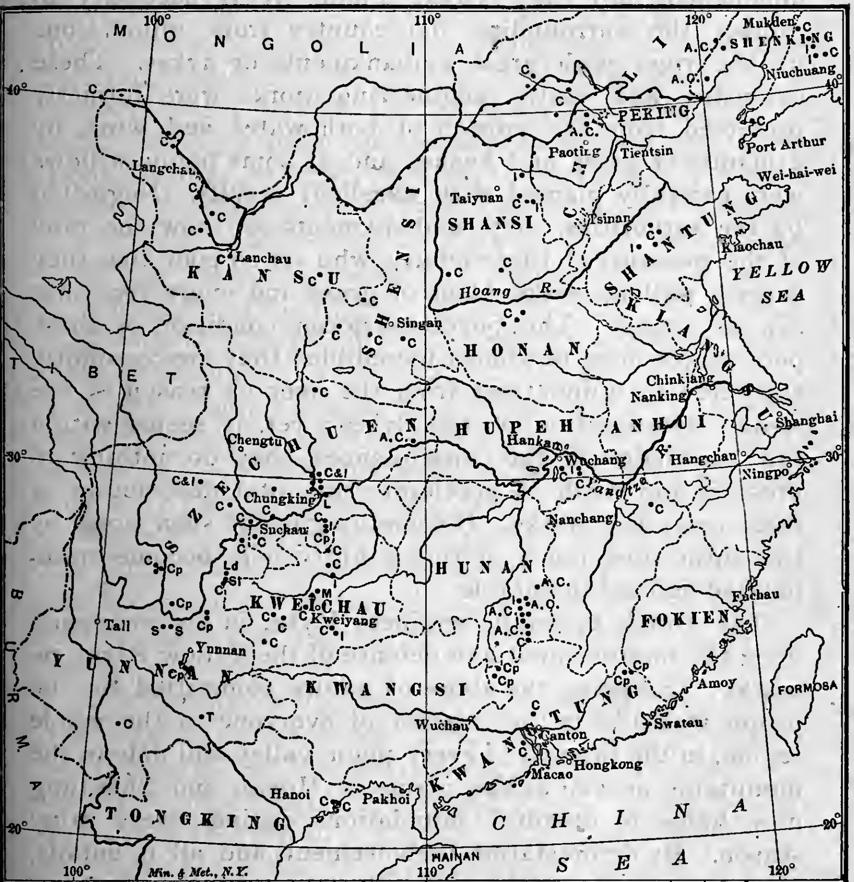
* "Richthofen Letters." Shanghai, 1870–1872, p. 37.

† "Mount Omi and Beyond." London, 1901, p. 257.

Little says the Chinese have a regular locust-like propensity to destroy every green thing wherever they penetrate; for when the trees are gone, comes the turn of the scrubs and bushes, then the grass and at last the roots, until finally the rain washes down the accumulated soil of ages and



C Coal A.C. Anthracite Cp Copper I Iron Ore L Lime M Mercury S Salt Si Silver T Tin Ld Lead

[*By courtesy of "Mining and Metallurgy," New York.*]

barren rocks remain. While this statement may be rather extreme, there is reason to believe the rainfall has considerably diminished in many portions, and is much more irregular and uncertain. All observers agree that the rivers have shrunken in volume and droughts occur where they

had been quite unknown. According to Little, in north-western Szechuen, in what is known as the "red basin" situated at the foot of the mountains, there have now been successive seasons of drought.*

On the Yellow River below Kai-fung-fu, after it has debouched into the "Great Plain," it is necessary to protect the surrounding flat country from inundations by the river with great embankments or dykes. These extensive and costly engineering works were formerly protected from the erosion of both water and wind, by a mantle of grass and bushes and at some points willows were carefully planted with excellent results. Neglected by the authorities, these embankments are now the prey of the peasants of that vicinity, who are so poor that they eagerly pull up every blade of grass and every root that can be found. The poverty-stricken condition of these poor people must be almost incredible; they are constantly subjected to inundations from the river by reason of the steady deterioration of the dykes; yet, it seems with a full knowledge of the consequences, they do nothing to preserve and much to accelerate the total destruction of these protective works. If something is not soon done by the authorities much of this country will become uninhabited and uninhabitable.

The Dutch hydraulic engineer Ryke, in his comments upon the improvement and defense of the Yellow River, remarks: "Stopping the abuse of nature committed by the people would be in the interest of everyone in the whole region, in the interest of every plain, valley and dale in the mountains, as well as the plains in Honan and Shantung now liable to dreadful inundations during every rainy season. By deforestation (deboisement) and all it entails, almost every mountain and hill stream has become torrential, and this means that the rainwater leaps downward in waves as soon as it falls; it means further, as a matter of course, the misery of a water famine in dry seasons." Ryke affirms that upon several occasions when it was neces-

* *Ibid.*, p. 257.

sary to examine a mountainous section of country for the sake of a stream, or for plains liable to inundation, he had only to look on the map of the district to know beforehand where to find the worst cases and they were invariably where the greatest number of villages and hamlets were indicated. He means of course by this that the evil results of deforestation are in a direct ratio with the number of habitations and density of population. Williamson, in his remarks on his journey through Shansi, states that on the roads leading through defiles stones are erected with inscriptions warning passengers against the sudden rush of waters in case of a rain storm. "*At this place beware of the mountain water,*" and "*travellers should not take shelter from the rain here,*" are the notices posted in many places.*

Some idea of the rapidity of the run-off in the mountainous sections of China can be obtained by gaugings at Chungking in Szechuen. According to Little, on July 6th, of one year, the Yangtse River stood 38 feet 6 inches above the mean winter level; in consequence of heavy rains in Yunnan it rose by the 13th of this month to 96 feet 8 inches, and fell again by August 3d to 28 feet above the winter level. It rose again on August 16th to 57 feet, this rise being due to the rains in the basins of the Ta and Tung Rivers in western Szechuen. After this date the river suffered comparatively slight fluctuations, steadily subsiding towards the lowest February level†.

If additional evidence is needed of the effects of deforestation in China, the indisputable fact of a steadily creeping southward of the Mongolian deserts might be cited. The once rich provinces of Shensi and Shansi appear to suffer most from this inroad of chronic desiccation with its resulting famines. Since about 1845 there has been a steady decrease in the population of the provinces bordering on the deserts, namely Shansi, Shensi, Kan-su and Chili. No doubt this has been due in some measure to other causes,

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*** Rev. A. Williamson, Journal North China Branch, Royal Asiatic Society. New Series.**

† "Mount Omi and Beyond." A. J. Little. London, 1901. Pp. 119.

such as the Taiping rebellion and other political disorders. But the probabilities are that cultivatable area in these provinces is steadily shrinking, and has in a great degree been caused by the destruction of the protecting forests. In this connection we have some grounds for an interesting speculation as to whether or nct certain well developed facts warrant the belief that much of the territory now desert was a habitable and fertile country in historic times. It is not possible to discuss the subject in this paper, save to say that unmistakable evidences of a comparatively high civilization have recently been discovered in the midst of what are now and apparently have long been hopelessly desert areas. It may, perhaps, be going too far to assume that the climatic changes which have brought about such results have been entirely due to deforestation. The probabilities are that other forces have been at work, but until the problem has been intelligently studied, it is hopeless to attempt its solution. Careful and scientific observations of rainfall, flow of streams, etc., have yet to be made in China. It is only at Shanghai and Hong-Kong that metereological data covering any considerable period of years have been accumulated.

Marco Polo speaks of the Yangtse River as being thickly wooded in places where a tree is not now to be seen for miles. According to the naturalist Pratt, there are now no trees worth felling in the Yangtse valley within any distance of a stream that might be used for logging.*

Another naturalist, Père Amand David, cannot believe this reckless destruction of the forests which characterizes the march of Chinese civilization to be altogether due to the need of firewood. He attributes it rather to the fear of wild beasts and a desire to destroy any cover for them. In Szechuen and in a number of other provinces of the Yangtse drainage area, the natives mine and use considerable quantities of coal. Where this is abundant and cheap, it is not likely they are under much stress for fuel, as is the case in the "Great Plain," and along the banks of the Yellow River

* "The Snows of Thibet and through China." A. E. Pratt.

below Kai fung-fu. The theory of Père David's may, therefore, be correct, for the Chinese, as a rule, certainly have great fear of the tigers that are usually found in the wilder parts of China.

It is rather remarkable that so practical a people as the Chinese should not have long ago recognized the many advantages of forest culture, that is, in the sense of raising trees as an agricultural product. It seems, however, insome localities, nota-bly in Hunan province, attempts have been made at replanting the hillsides with ordinary timber trees. But this is quite exceptional, for, as a rule, only those trees are considered worth growing that yield a comparatively quick return or harvest. The yield of the varnish tree (Rus vernicifera) the camphor (Cinnamomum camphora), mulberry (Morusalba), mountain oak (Quercus esculus), and the bamboo (Bambusa) form alarge portion of the natural products of China, the mulberry being, of course, used in silk culture as is likewise the mountain oak.

The usual Chinese system of cultivation by means of terraced fields rising one above the other up the side of a hill or even mountain, does certainly tend to check erosion. These systems of terraced paddy fields are generally placed where possible athwart the course of small streams.

The French use barriers of a similar kind especially constructed to check erosion, and enable the soil to accumulate on steep hillsides in sufficient quantity to give foothold and sustenance to trees. In China one often sees, especially in those provinces ravished by the Taiping rebellion, abandoned fields of this kind covered with small trees or bushes, showing thus that the hillsides could be easily planted with trees were it possible to give up their use for agriculture.

It has been estimated under normal conditions in well forested areas, that about one-sixth to one-third of the whole rainfall flows off into the sea, the five-sixths or two-thirds sinking into the earth, where it is conserved to supply springs and wells. It follows, therefore, when the protecting cover is removed, there is little less to hold the water from immediately running off, consequently less and less soaks into the earth and the level of the ground water

steadily decreases, drying up the springs, wells and ooze that is very beneficial to vegetation. This statement has been so well substantiated by careful observations in Europe and America it scarcely needs reiteration. The existence of forests probably increases the amount of rainfall, because fogs and clouds, saturated with aqueous vapor, which sweep over it, are condensed by contact with the leaves and branches. Furthermore, the temperature of the air in forests is considerably lower in daytime and higher at night than that over cleared areas; this condition presumes a local circulation of the air, which has the effect of driving fogs or clouds into its bosom and a consequent deposition of the contained moisture. But probably the most potent effect of trees in conserving rainfall is from the fact that much of the rain is temporarily held by the leaves and falls to the ground slowly, giving it a longer time to soak into the ground. Forests also render this process more easy by the roots, which spread out over a large area, forming channels through which the rainfall filters and sinks deeper and deeper into the earth. It has been estimated by experiment that the aqueous vapor which forms over cleared fields is at least four or five times as great as that over a wooded tract, and consequently that the water which has oozed into the soil of the latter does not vaporize so easily, but is retained and serves to feed the surface springs and rivers.

It seems most extraordinary that a practical, intelligent and observing people like the Chinese should have failed to recognize some of these facts, and that seeing their country becoming steadily more and more arid and difficult to cultivate, some effort should not be made to mitigate or check the evil.

At the present time the normal annual rainfall at Peking is 16 inches and as the coast is approached it increases steadily. As far as I know no records have been kept in eastern Shantung; hence any estimate of the annual precipitation at say Chee-fu and Wei-hai-wei is a mere conjecture. Starting with 16 inches at Peking as a basis and studying carefully the conditions of the country between there and Chee-fu we may assume the rainfall in eastern Shantung

at 40 inches. According to Chinese historical records the climate of northern China has undoubtedly moderated considerably from what it was some centuries ago. This has been correctly attributed to the effects of deforestation. While the total annual precipitation has probably not greatly decreased, it is unevenly distributed, drought follows flood, and there are distinctive wet and dry seasons that are unusual in a temperate climate in much the same latitude as Philadelphia and surrounded on three sides by the sea.

At Hong-kong, Macao and Canton the annual rainfall is great, averaging 86 inches, and in 1891 was exceptionally high at 117 inches. In northern China the rainy season lasts about two months, July and August approximately. While the ill effects of deforestation in many portions of China are sufficiently obvious, it is not so easy to draw conclusions as to resulting influences upon the character of the people. Poor and unhappy they certainly are, overpopulation has stretched the food-supply about to its elastic limit. A failure of crops in any section entails starvation on the part of most of the inhabitants in that district, for transportation is usually so crude and costly, that supplies from other parts of the Empire cannot be delivered at a cost that will be within the ability of nine-tenths of the people to pay. Some sections are of course more fertile and favored than others, but it is evident in the best of them such dense populations cannot long continue to live by the soil alone. Unless therefore the Chinese encourage and extend their manufacturing industries and particularly develop their marvelous mineral resources, they cannot prosper, but will revert to savagery. The whole Chinese question, both political and religious, therefore, resolves itself into a purely industrial one. At the present time the Chinese nation is undoubtedly decadent, but the people as a whole certainly cannot be so considered. Political corruption, an absurd conservatism and self-conceit are the bane of the country. Yet political corruption is not unknown in other countries, and we regret to think even in those that supply the Chinese with most of their foreign moral and religious instructors. In a word, the Chinese house is worn out, it is filthy and rotten; place

its inhabitants in a clean new one and they will astonish the world with their prosperity and progress, moral, religious and industrial.

METALLURGY OF ALUMINUM.

The following item, gleaned from the "Digest" department of the *Electrical World*, may be classed as "highly important, if true," viz.:

Metallurgical processes which involve the use of calcium carbide as the reducing agent, possess an especial interest due to the fact that they are, in an indirect manner, electro-chemical, for the energy used for the reduction is as truly electrical as though the effect was produced directly by electrolysis instead of indirectly through the medium of the carbide furnace. Hence a discussion of such processes always involves the question of relative efficiencies as between fused bath electrolysis and electric furnace reduction—a question which generally solves in favor of the furnace. This question is raised but not answered by a patent recently issued (May 28) to Mr. Henry Spencer Blackmore, of Mount Vernon, N. Y., for the reduction of aluminum compounds by the reaction therewith of a carbide. Mr. Blackmore finds that aluminum oxide is reducible by aluminum carbide with liberation of the metal of both reacting bodies and in accordance with the equation $Al_2O_3 + Al_4C_3 = 6Al + 3CO$, the reaction being strictly analogous to that employed by M. Moissan some years ago for the preparation of metallic chromium. If, however, the oxide and carbide of aluminum be employed in the solid state it is found that the aluminum is either volatilized or so distributed through the residual charge as to render its collection impracticable, and accordingly it is proposed to suspend or dissolve the oxide and carbide in a molten bath, which remains inert with respect thereto, and which so reduces the temperature of the reaction and so alters the character of the medium as to permit the liquid metal to be tapped off. Two procedures are described: In the first, a mixture of cryolite and lithium fluoride is fused, and the oxide and carbide of aluminum are alternately added, the reaction occurring readily, it is said, and the aluminum separating freely. In the second, oxide of aluminum is added to the bath and calcium carbide then introduced, the effect being to produce aluminum carbide within the bath by reaction between the cryolite and the carbide of calcium, this aluminum carbide then reacting with the oxide present to yield the metal. The calcium fluoride formed interferes to no marked degree with the operation, and in the early stages serves to promote the fluidity of the metal. Eventually, however, the bath must be regenerated or renewed. Mr. Blackmore is authority for the statement that he has succeeded in producing aluminum by reduction by calcium carbide, on an experimental scale, at an expense not exceeding 7 cents per pound. W.

Section of Photography and Microscopy.

Stated Meeting, held May 2, 1901.

THE CHAPMAN JONES PHOTOGRAPHIC PLATE TESTER.

BY FREDERIC E. IVES,
Member of the Institute.

This device, which was demonstrated by Mr. Frederic E. Ives, at the stated meeting of the Institute, in May, is thus described by the inventor:

The object of this apparatus is to provide an easy and rapid means of ascertaining, within a sufficient degree of accuracy to be of practical value, the relative working characteristics of photographic plates and films. It consists essentially of a screen plate 4¼ by 3¼ inches, containing:

(*A*) A series of twenty-five tints of graduated densities.

(*B*) A series of colored squares and a strip of neutral gray, all five being of approximately equal luminosity.

(*C*) A series of four squares of special colors, each color passing light from a definite portion of the spectrum, and

(*D*) A square of a line design over which is superposed a half-tone negative.

In order to use the instrument, a quarter-plate of the brand to be tested is simply exposed behind the screen for a few seconds, developed, fixed and washed.

Simple examination of this one plate will show sensitiveness, or speed, sensitiveness to color, range of gradation, comparative size of grain of plate, possible range of exposure, amount of halation, the most suitable light for development. By further exposures, the instrument can be used for testing and adjusting developers, testing media for dark-room illumination, examination of light filters, testing plate backings, etc., etc.

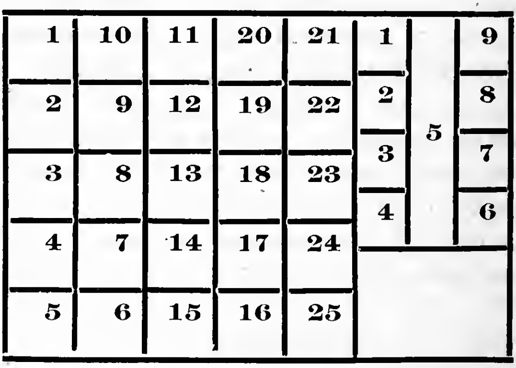
Although nearly all makers give some indication on their packages with regard to speed and other characteristics of

their plates, the conditions under which they make their tests are not uniform.

One very great advantage of the little instrument is that it enables the actual user of plates to ascertain quickly and with a minimum of trouble, the *comparative* usefulness of the various brands on the market for his *own special purpose.* The record obtained is a permanent one, always ready for reference.

THE APPARATUS.

The Screen Plate.—The essential part of the apparatus is the screen plate shown in *Fig. 1.* The screen, which is of the same size as the ordinary quarter-plate, $4\frac{1}{4}$ by $3\frac{1}{4}$ inches, contains:



(*A*) A series of twenty-five tints of graduated densities, each numbered for identification, but in such a way that the larger part of each tint is available for comparison with other tints or for measurement.

(*B*) A series of four small colored squares and a strip of gray, Nos. 1 to 5, all five being of approximately the same luminosity and constituting what is known as the Abney Color Sensitometer in its simplest form.

(*C*) A set of four squares of special pure colors each of which represents a definite portion of the spectrum, the division of the spectrum into parts being made in such a manner that the information given is just that which is most useful.

The square 6 transmits all the light to which ordinary plates are usefully sensitive (ultra-violet, violet and blue, as far as the Fraunhofer line *E* or *b*).

Square No. 7 transmits the green to which isochromatic plates are sensitive, in addition to the sensitiveness of ordinary plates (*E* or *b* to *D*). The first red (No. 8), transmits only the red to which some orthochromatic plates are sensitive, when the extreme red is reserved as a useful light for the dark room, namely *D* to *C*, and the last red patch (No. 9), transmits only the red beyond *C*, these four patches therefore divide the spectrum into four definite portions, the remaining portion of the area of the instrument is occupied by a line negative over which is superposed a half-tone negative from a plaster relief. This half-tone negative being about the density of an ordinary (*thin*) negative gives an indication, the value of which every photographer will at once recognize.

It is only necessary to expose a plate for a few seconds behind this screen and develop it, when the resulting negative shows at a glance all the information the photographer usually desires, and no scientific knowledge is necessary to interpret the result. By further examination of this plate, results of a quantitative character can be obtained. Several tests are made at one time, but the different parts of the apparatus do not interfere with each other or necessitate compromises; indeed, they add to each other's value.

Mr. Ives said he believed that all of the separate tests included in this device had been used before, but that their combination in a single handy device was due to Mr. Chapman Jones, and that Mr. Jones by his suggestion, and Mr. Sanger Shepherd, by the very efficient manner in which he had provided for quality and uniformity in their manufacture, had conferred a boon upon the photographic fraternity. He thought that every photographer should know his tools and there could be very little excuse for anyone to remain in ignorance of the capabilities and limitations of his photographic plates when such a cheap and handy device could be made to tell practically all the story.

EFFECT OF HEAT ON BABBITT METAL.

Almost any solid metal for lining bearings is called by the name "babbitt metal," while in fact few of the soft linings used have any claim whatever to that title, says *Modern Machinery*. The genuine alloy which was compounded by John Babbitt, and which bears his name, is composed of eight parts regulus of antimony (regulus means the pure, refined metal) four parts copper and ninety-six parts of tin.

Ordinary soft lining, so-called babbitt metal, frequently is made up of four parts lead and one part antimony. Old type metal is also used for lining, and consists of two parts lead, one part tin, and one part antimony. Britannia metal (pewter) is much used for lining, and this consists of nine parts tin and one part antimony.

It will be noted that all the alloys above described are partly of antimony, and also contain either lead or tin, both easily oxidized metals. But antimony is even more easily oxidized, and will burn in the open air if too highly heated, much like zinc. Thus, when either of the alloys described above is frequently heated, the different metals become oxidized, but burn out in different ratios to each other, thereby changing the nature of the alloy to a certain extent each time it is heated.

Genuine babbitt will probably change its form more by reheating than the alloys of antimony and lead, but the latter are reduced the most in quantity. The reason, therefore, is that the copper and tin oxidize more slowly than the antimony, which quickly burns out, leaving the babbitt much softer than it was before getting rid of some of its antimony. Lead oxidizes much more freely than either copper or tin, therefore the alloy retains more nearly its original composition when a quantity is burned off or oxidized; still the antimony burns out faster than the lead, reducing the hardness of the alloy, but not to the extent it does when mixed with tin and copper. Under proper conditions, any kind of babbitt metal may be melted, and even kept indefinitely in a molten condition without oxidation, or, in every-day language, without the forming of dross on the surface of the molten metal. To secure this result, protect the metal from the atmosphere. A layer of dirt on top of the molten metal will do it; even a layer of oxide or dross is a good preventive; therefore do not skim off the layer of oxide as fast as it forms, but let it stay on top of the hot metal.

A very good way is to cover the metal in the ladle or melting pot with pulverized charcoal. Carbon largely retards the process of oxidation, and if some salt and soda (common washing and cooking soda) be added to the coarsely-powdered charcoal, the oxide will be reduced—that is, the dross will be smelted back into the metal again.

Another preventive of oxidation of babbitt metal lies in not heating the metal too hot. For all except very small bearings, where the layer of metal must run very thin, there is no need of heating the metal very hot. Just hot enough to barely char a dry pine stick, is a good rule to follow when heating babbitt metal. But whittle the stick every time the metal is tested, so that a fresh wooden surface is exposed thereto.

Section of Photography and Microscopy.

Stated Meeting, held May 29, 1901.

A NOVEL FORM OF LANTERN POLARISCOPE.

BY FREDERIC E. IVES,
Member of the Institute.

Owing to the high cost of large Nicol prisms, lantern polariscopes with stages large enough to take the regular mica and selenite designs, chilled glasses, etc., are now almost always made with bundles of glass as polarizers, and in order to avoid turning the lantern aside, as was necessary

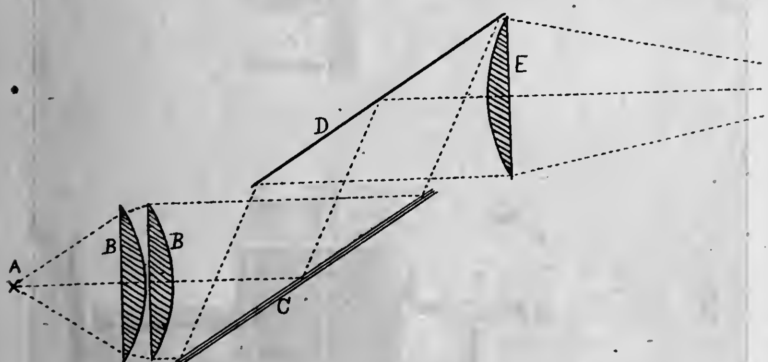


FIG. 1.—Diagram of lantern polariscope.

with the old elbow form of polariscope, an arrangement is used in which the rays are reflected forwards again after polarization, as shown in *Fig. 1.*, in which *A* is the source of light; *B B* condensing lenses for parallelizing the light rays; *C* the bundle of glasses for polarizing by reflection at the angle of 57°; *D* a silvered mirror; *E* a convex lens for bringing the light rays to a focus within the small Nicol prism used as an analyzer. The stage is just in front of *E*, and is not nearly as convenient for many purposes as a horizontal stage would be.

For my own use, and to meet certain special requirements, I recently constructed a lantern polariscope in which the

position of the reflecting surfaces *C* and *D* is so altered as to bring the stage into a horizontal position, and at the same time that portion of the light transmitted by the glass bundle is utilized for ordinary projection purposes, and ordinary slides or other optical demonstrations can be interspersed with or superposed upon the polariscopic projections. This

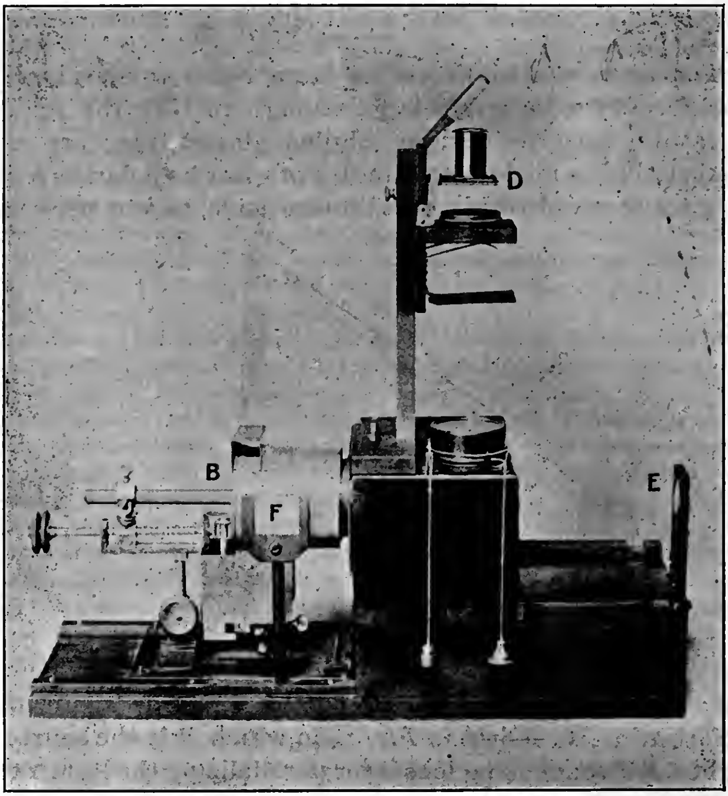


FIG. 2.—Ives' lantern polariscope.

instrument having attracted some attention and been favorably commented upon when used at recent meetings of the Institute, I have been induced to furnish the following description for publication:

The general disposition and appearance of the instrument is shown in *Fig.* 2, in which *A* is a light wooden platform; *B*

is a "right angle" hand-feed electric lamp, as made by the McIntosh Company, of Chicago; *C* is a light, rectangular wooden box, with hinged lid, containing the polarizing and silvered reflectors, and carrying the condensers and stages. *D* is the polariscope objective, analyzer and right angle reflector, and *E* is the objective for ordinary lantern slide projection; *F* is a small ground glass upon which is projected an image of the electric arc, through a "pin-hole" opening in the sheet-iron hood.

Fig. 3 is a horizontal section of the box *C* of *Fig. 2*. *A A* are the condensers for parallelizing the rays from the source

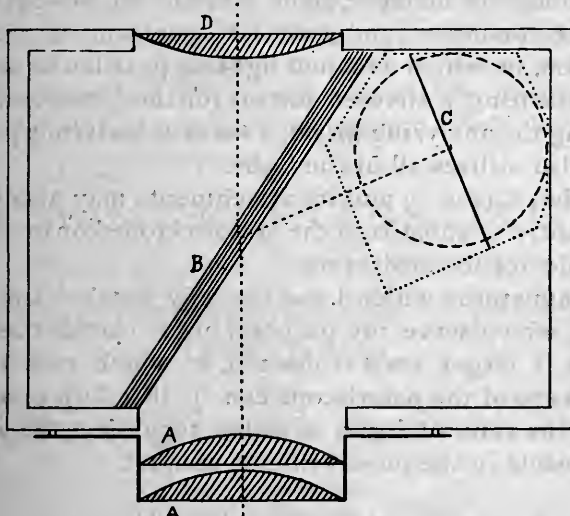


FIG. 3.—Plan of Ives' lantern polariscope.

of light. This condenser system should be perfectly aplanatic for the best results, but the combination indicated in the plan answers very well with the electric arc light. *B* is the polarizing bundle, made up in my own instrument of twelve sheets of special extra thin polished plate glass. The twelve sheets make a bundle $\frac{3}{8}$ of an inch thick. *C* is a silvered mirror so inclined in the horizontal plane as to project the polarized rays vertically upwards through a condensing lens, which cones them into the objective and analyzing prism. *D* is the condensing lens for coning the

direct rays into the objective for ordinary projection. The objective which I use is a single plano-convex achromatic lens, which is perfectly efficient with the electric arc light if the condenser is of suitable focus. It is attached to the box in which the analyzer combination is packed, and which slides within the lantern base to focus. Both objectives are supplied with a simple form of shutter.

The objective for polariscopic projection is of somewhat longer focus than that for ordinary projection, giving a smaller disk, and so making the illumination of the two disks about equal. By removing the glass bundle, which can be done in a moment, all of the light can be sent through the front condenser and used for spectrum or microscope projection, in which as much light as possible is desirable. By substituting a silvered mirror for the glass bundle, and removing the analyzing prism, a vertical lantern is produced, which also utilizes all of the light.

The box *C* (*Fig. 2*) and its attachments may also be lifted off instantly to substitute the lantern kromskop or any other special device for projection.

The apparatus which I use has only 3-inch diameter condensers, which serve my purpose, but it can just as well be built on a larger scale if desired, in which case the horizontal stage of the polariscope can be lifted up to a smaller part of the cone of light, in order to project the ordinary sized objects in the most brilliant manner.

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THE FRANKLIN INSTITUTE.

Stated Meeting, held Wednesday, April 17, 1901.

THE TAYLOR-WHITE PROCESS OF TREATING TOOL STEEL, AND ITS INFLUENCE ON THE MECHANIC ARTS.

BY CHARLES DAY,
The Link-Belt Engineering Company,
Member of the Institute.

I have been asked to give you this evening, a brief description of the Taylor-White process of treating tool steel, with special reference to our work at the Link-Belt Engineering Company (Nicetown, Philadelphia).

I will first take up the process, which has been but recently patented here and abroad. The first experiments, which led to the very thorough investigation later, and finally to the Taylor-White process, were carried out between three and four years ago at the Bethlehem Steel

Works (South Bethlehem, Pa.) by Messrs. Taylor and White. At that time "Mushet" and "Jessop" tool steels were in general use throughout their shop, the former representing the best grade of air-hardening steel on the market. The usual method of hardening all air-hardening steel is well known, and the manufacturers in nearly every case place great stress on the fact that the tool must not be heated above a cherry red, otherwise it will be burnt, and so ruined. Not being satisfied with the limited information at hand on this matter, and having had some curious experiences with so-called burnt tools, Messrs. Taylor and White decided to make an investigation of the matter on a thoroughly scientific basis.

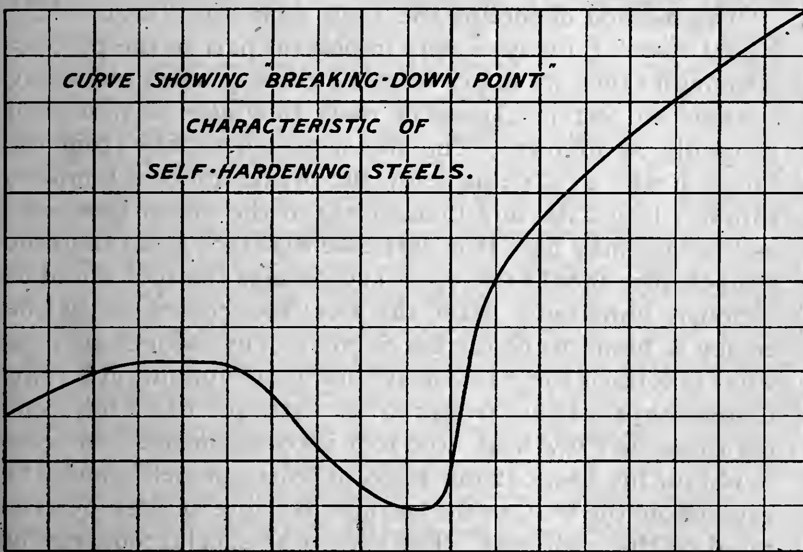
Many grades of air-hardening steel have been on the market for several years, and for roughing work have unquestionably replaced the carbon variety, the efficiency of the former ranging from one and a half to twice that of the latter. This gain is due to the fact that air-hardening steel holds its cutting edge at much higher temperatures than carbon steel, and consequently can be worked at proportionately greater cutting speed. The object in view in carrying out the experiments above referred to, was to obtain a tool steel which would give still better results than those already obtained, and how successfully this end has been attained is only too well known by those interested in machine-shop work.

The experiments consisted essentially in a long series of tests made upon tools of various chemical compositions, and heated to different temperatures. These tools, after being carefully ground to the desired angles, were tested in an experimental lathe, provided with a motor drive and an "Evans" friction cone, in order to obtain any desired cutting speed. Most careful records were made of all these tests, which extended over several years. The results which were finally arrived at, and recently patented, are truly astonishing, the treated tools showing an efficiency ranging from one and one-half to two and one-half times that of air-hardening steel treated by the old method.

The discovery of the new process depends largely on the

fact that, although both carbon and air-hardening steel deteriorate rapidly when the temperature rises above a cherry red, some chemical compositions of the latter class rapidly pass through this condition, the efficiency rising slowly at first, and very rapidly as the temperature rises, reaching a maximum at the point where the tool crumbles when tapped with a rod. This action can best be shown graphically, the abscissæ representing temperatures, and ordinates cutting values.

Link-Belt Engineering Company, Nicetown, Philadelphia.



1,450 1,500 1,550 1,600 1,650 1,700 1,750 1,800 1,850 1,900

Temperatures.

This curve does not represent any particular piece of steel, but is intended to give a general idea only of the variations of the temperature to which the tool is heated, and the accompanying cutting values. The point to which air-hardening steel was formerly heated in the process of hardening is shown on the graphical sketch between 1,550° F. and 1,600° F., and has been called the "breaking down point," and varies, as do the other points, with different compositions of steel. The composition found to give the

best results consists of an air-hardening steel containing at least ½ of 1 per cent. chromium and 1 per cent. or more of another member of the same group, tungsten being found to give the best results. Much better results are obtained, however, by using about 1 per cent. of chromium and about 4 per cent. of tungsten; while for very hard metals, such as the chilled scale on cast iron, etc., 3 per cent. of chromium and 6 or more per cent. of tungsten are especially good. It may be interesting to note that the variation in carbon seems to matter but little, steel varying from 85 to 200 points giving equally good results.

The method of cooling the tools from the "high heat" (about 2,000° F.) plays a very important part in the process. Although there are many ways of cooling, each one being adapted to certain classes of tools, they may be described generally as follows: The tool is cooled rapidly from the "high heat" to a point below the breaking-down temperature in a lead bath, and then slowly in the air, or lime, etc., as the case may be. It is very essential that at no time the temperature should rise, as in such a case the tool would be seriously impaired. After the steel has cooled off, its efficiency is found to be further increased by subjecting it to what is termed the "low heat" for about ten minutes; this temperature ranging from 700° F. to 1,240° F. After cooling from the "low heat" the tool is ready for use. In order to obtain the best cutting edge, at least $\frac{1}{16}$ inch should be ground off the tool, as the surface is more or less deteriorated by the high heat. The surface of special tools can be protected, however, by some form of flux, thus making it possible to treat milling cutters, etc., by this process. The treatment in all cases extends well back from the point of the tool, and permits of its being ground until so weakened as to require reforging. It is not essential to anneal the steel when reforging, and it might be well to add that all these tools can be worked with comparative ease.

In the operation of the Taylor-White process apparatus is employed by means of which temperatures can be controlled within very narrow limits, which accounts for the uniformity of results obtained with the tools treated by this

process. It has been found necessary to modify the treatment of the special steel used in this process in order to obtain the best results under different conditions, such as varying kinds of metal cut on different types of machines, such as lathes, planers, slotters, drill presses, etc., so that no less than ten different modifications of the treatment are used in the preparation of tools for a large and fully equipped shop working on different kinds of metals and with various classes of tools. The variations required, however, in the treatment are of the most simple and easy application after once being understood, and can be handled with the full degree of success by an ordinary trained laborer.

This apparatus offers the still further advantage of hardening and tempering all classes of carbon steels, such as ordinary tempered tools, taps, reamers, milling cutters, etc. By careful operation of the process the best temperatures at which to harden and temper are soon learned, which will insure a uniformity never before attained in these tools.

The very brief description which I have just given, is but an outline of the Taylor-White process, the details of which are most interesting, representing, as stated above, the results of the most thorough scientific investigation. It was particularly fortunate that this discovery was made at the Bethlehem Steel Company's works, where the facilities for carrying on the experiments were of the very best. If this had not been the case, in all probability the process would never have reached its present standard or uniformity. The latter quality is of the greatest value, as will be explained later, and is possessed by no other tool steel. Over 200 tons of steel forgings were cut up in carrying out this work, and the total cost aggregated about $100,000.

A better example could not be found of the modern methods adopted in attacking problems of this nature. They bring rich results in nearly every case. Any number of examples could be cited, but probably one of the most interesting, and, at the same time, richest in results, was the work of Captain Jones on the ingot mold at the Edgar Thompson Works at Pittsburg. These molds, in nearly every

case, cracked after a few ingots were cast, the expense this involved being enormous. Realizing the necessity of more durable molds, and learning from experience that some fulfilled the requirements much better than others, Captain Jones undertook an investigation on the lines we have referred to above, the results paying a handsome dividend on the entire plant. And so it is in every line of manufacture, that the concern which has the facilities and is willing to spend the necessary money for work, which, at first sight, often seems entirely unnecessary, makes strides which not only cheapen its own product, but affect the entire business world.

The Taylor-White process of treating tool steel is particularly of this character, and has already wakened up machine shops all over the country to the fact that methods frequently known as "good shop practice" are anything but *good*, and if they expect to keep up with the times they must adopt different plans and more radical methods.

It will now possibly be well to consider some of the savings effected at the Link-Belt Engineering Company's works since this process was introduced. The class of work in this company's machine shop being radically different from any encountered by Messrs. Taylor and White up to the time we adopted the process, the first few months were devoted almost entirely to experimental work, the steel having been in general use throughout the shops for only a couple of months. For this reason it is impossible to give any data extending over considerable time, but a few examples taken at random will convey a fair idea of gains we have made.

About 97 per cent. of our material is cast iron, requiring much handling and relatively little machine work. In order to make a rough test on cast iron, one tool was obtained from Bethlehem and put to work on a 7-foot boring mill turning the inside of a cast-iron ring. The time required to do this work with our old tools had been determined many times in setting piece rates, and was about fourteen hours. With the Taylor-White tool this time was reduced to three and one-half hours, and a gain of 75 per cent. made. To be

sure, the steel used heretofore was not the best obtainable, and, besides, was probably not worked to its highest efficiency, but the saving, nevertheless, was due to the Taylor-White process, and so it is that many shops of the best standing could, after introducing this "process" and watching it with proper diligence in the shop, show savings considerably in advance of those claimed by the inventors. I do not wish to infer that there are not shops in existence who push every tool to its limit, but they are decidedly the exception.

Some interesting data was also obtained from an order of rope sheaves, the time required to do similar work having been tabulated for several years. The average time required to machine thirteen sheaves with our old tools was nine and one-half hours, the same for sixteen similar sheaves, the roughing being done by Taylor-White tools, was five hours and five minutes, or a saving of 46½ per cent. In order to obtain, however, a correct comparison of the relative merits of the tools used for roughing, it is necessary to analyze the various operations.

	Hours.
Setting up	·9
Forming groove with special tool	·5
Boring and polishing	·25
Roughing	3·43
	5·08

Assuming the time for setting up, forming, boring and polishing the same when sheaves were finished with old tools, the time for roughing would have been 7·85 hours. From these figures, we see that a saving of 56·3 per cent. was made in operations where it was possible to use treated tools.

The entire order of sheaves above referred to, many of which were small, the roughing cuts being but a small percentage of the machining, required 1,569 hours' work. This was a gain of 501¼ hours, or 31·95 per cent. over our *best* previous records, and gives a good idea of what may be expected on work of this class.

Tools treated by this process are not intended for finish-

ing, but rather for heavy cuts, where the tool is subjected to high heat. We have experimented quite a little with special tools, and have been very successful with boring cutters, the actual time for boring being reduced frequently 60 per cent. Here the tool saving is not as great as the figures would suggest, as the time to chuck a sprocket is at present often greater than to machine the same. The trouble lies in the design of the lathe that handles our sprockets, which we are at present remodelling in order to reduce the time of chucking, and similar operations to a minimum. A test made on boring cutters treated by the process shows conclusively their superiority for this work. It consisted in boring 1 $\frac{3}{16}$ inch standard solid collars in one cut, the core being one inch. The lathe was speeded up until the work at the point of the cutter was going 77 feet per minute. The regular cutter lasted but ten seconds, while the treated ones bored four (4) collars successfully.

In order to obtain some data with regard to pressure on the points of tools for given depths of cut, feed, etc., and at the same time to show the superiority of the treatment we are considering, a cast-iron ring 6 feet 6 inches in diameter was bolted to the table of a 7-foot boring mill and the results obtained tabulated below:

The first tool used was one treated for hard material. It cut 106 pounds of metal in 10 minutes, and when removed was in perfect condition. A "Mushet" tool under the same conditions lasted but one minute, and removed $5\frac{1}{2}$ pounds of metal. The actual pressure against the tool in each case exceeded $3\frac{1}{4}$ tons, while the pressure per square inch with the Me. S. H. tool was 143,000 pounds. Friction of the tool against the work was not considered in the above, and would vary the results somewhat.

We will now turn our attention to steel for a few moments, and although we have very little roughing work of this character I can recall several instances where good savings were effected, any one of which will serve as an example. One of our standard forms of internal screw conveyor is provided with steel tires about 40 inches in diameter and 40 points carbon. These are machined all over, the

Link-Belt Engineering Company, Nicetown, Philadelphia.

NO.	TOOL	MATERIAL	CIRC. SPEED		FEED		DEPTH CUT	LENGTH CUT		POUNDS METAL	AMMETER		VOLTMETER		HP		LBS. METAL PER HOUR	CONDITION TOOL	PRESSURE ON TOOL	
			IDLE	CUT.	CALCULATED	ACTUAL		INCHES	MIN.		IDLE	CUT.	IDLE	CUT.	IDLE	CUT.			ACTUAL	PER SQ. INCH
1	H.S.H. $\frac{7}{8}'' \times 1\frac{3}{4}''$ TREATED	C. I. SCALE	86	78	$\frac{1}{16}$	.056	.91	$2\frac{5}{16}$	10	106	32	145	112	106	4.80	20.5	636	GOOD	6650	130,000
2	M.E.S.H. $1'' \times 2''$ TREATED	"	86	77	$\frac{1}{16}$	.053	.91	$1\frac{5}{8}$	$7\frac{1}{2}$	80	33	145	112	108	4.96	21.0	640	FAILED	6905	143,000
3	MUSHETT $1'' \times 2''$ AIR-HARDENED	"	86	—	$\frac{1}{16}$	—	.91	—	1	$5\frac{1}{2}$	33	110	112	109	4.96	16.1	—	"	—	—
4	M.E.S.H. NOT TREATED	"	86	77	$\frac{1}{16}$	—	.91	—	$1\frac{5}{8}$	7	32	110	116	110	4.98	16.2	—	"	—	—
5	H.S.H. NOT TREATED	"	86	—	$\frac{1}{16}$	—	.91	—	$2\frac{5}{8}$	19	32	110	116	110	4.98	16.2	—	"	—	—

Tests made on cast-iron ring 6 feet 6 inches diameter. Boring mill, No. 191.

best time required for the entire operation of setting up, roughing, finishing, etc., etc., with our old tools being 14 hours; this was reduced to $9\frac{1}{2}$ hours, or a saving of 32·1 per cent. on the first order received after treated tools were in use.

Our experience on steel has been so limited that we will take the liberty to quote some figures obtained at the Bethlehem Steel Works, who have very kindly sent us some samples, which are before you, The table given below shows the chips cut in pounds per hour per tool, the data

Table showing increase in cutting speed, etc., in the machine shop of the Bethlehem Steel Company, since the introduction of the Taylor-White process.

AVERAGE.	OCT. 25 1898	MAY 11 1899	JAN. 15 1900	GAIN IN % CUT OF 3RD OVER 2ND	GAIN IN % CUT OF 3RD OVER 1ST
CUTTING SPEED	8'-11"	21'-9"	25'-3"	16%	183%
DEPTH OF CUT	.23"	.278"	.30"	8%	30%
FEED	.07"	.0657"	.087"	32%	24%
LBS. METAL REMOVED PER HOUR	31.18	81.52	137.3	68%	340%
TENSILE STRENGTH	95,000	102,322	105,764*	$3\frac{1}{3}$%	$11\frac{1}{3}$%
% EXTENSION	.19%	.169%	.15%	$8\frac{1}{10}$%	
% CARBON	.44%	.42%	.42%		

* High tensile strength due to large amount of nickel steel being machined.

Average metal removed per hour, per tool (round nose) = 310 pounds.

April, 1901.

extending over the time the experiments were being developed, and are consequently, very interesting.

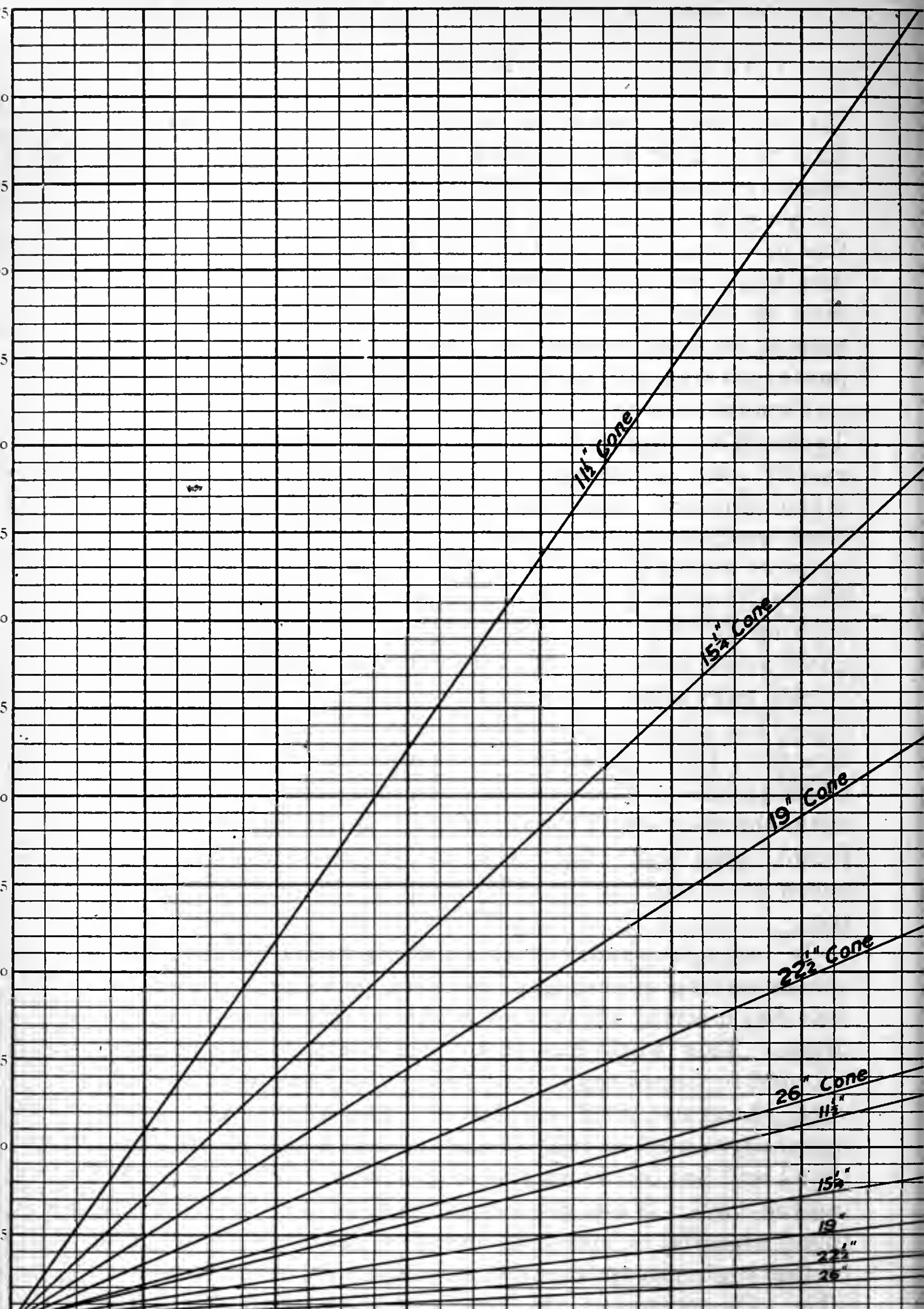
The steel chips which are before you show the characteristic colors which are the gauge for the speed foreman. A Taylor-White tool when working dry should cut blue chips continuously, so it is only necessary to turn off the water for a moment in order to see if the tool is working to its highest efficiency. The cutting speed may be increased about 30 per cent. if a good stream of water is kept on the point of the tool. It may be interesting to some to know

that the point of the tool is frequently red hot when cutting dry. This fact showing conclusively the high temperatures at which the cutting edge is retained.

We will now consider for a few minutes, the effect of this new process on machine tool design. I do not refer to very large tools and special machinery, which are usually built to fulfil given requirements, but to standard tools such as we find in every machine shop and which can be purchased from a large number of first-class concerns.

First, on account of the uniform results obtained by the Taylor-White treatment, it is possible to predict almost exactly what circumferential speeds should be used for any given material. To obtain close speed regulation with the cone method on such tools as boring mills, lathes, etc., requires multiple counter shafts, and is at best a poor rig where the work is small and the time of setting up and shifting belts a large percentage of the labor bill. The chart given below was made to facilitate the determination of the circumferential speed of work of any diameter on one of our 7-foot boring mills. I introduce it here to show how poor the regulation is. A rope sheave, for instance, 5 feet 0 inches in diameter could be roughed out at 52 feet with the belt on the 26-inch cone, gears in, but this is found, from past experience, to be too slow. The next speed of 77 feet on the other hand would soon destroy the tool.

In order to overcome this difficulty and for the many accompanying advantages, we have decided (at the Link-Belt Engineering Company's works) to introduce the motor drive. This work has just been started; the method adopted for speed regulation being the three-wire system, with rheostatic field regulation. The advantages of the motor drive were so fully discussed here a few months ago, that I will but touch on the matter now. After introducing the Taylor-White process at the Link-Belt works, it was found essential to speed up many of the tools on account of the high circumferential speeds which were made possible. On account of the variety of work handled and the fact that many tools do nothing but finish work, it was no



Scale, 1½ inches = 1 foot diameter.

Table of circumferential speed for work of any diameter. Boring mill No. 191.
August 30, 1900.

practicable to increase the line shaft speed more than 30 per cent.: the natural solution being motors; the machines becoming self-contained and permitting of any experimental work without shutting down the line.

As the machines were speeded up to obtain higher circumferential speeds, the power required to drive them idle was found to increase very rapidly, the limit of the line and engine being soon reached. An example may make this clear:

SEVEN-FOOT BORING MILL.

	Min.	Max.	Power required to drive table at max. speed. Horse-power.
Original range of table speed, .	·5	17·26	10·00
1st change, increased 25 per cent.			
2d "	·9	23·50	15·30
3d "	1·28	33·8	23·00 (approx.)

Eighteen months ago a 50 horse-power Buckeye engine furnished power to about forty of our machine tools, including three boring mills (10 feet, 7 feet, 6½ feet) our pattern shop and grinding room, the latter containing six carborundum wheels, four of which are frequently in use at one time.

The average horse-power developed has been determined frequently and averaged about 45. It required, however, about 27 horse-power to drive the line shafting and counters, thus leaving but 18 horse-power for actual work. After the new tools were in general use and the machines pushed to obtain the desired results, it soon became apparent that the power was absolutely inadequate; indicator cards from our engine frequently showed an overload of 60 per cent., and at this point we found it essential to put motors on some of our larger tools for the present, with the intention of using them entirely in the future as stated above.

Coming back to the machine tool manufacturers, it is quite remarkable how little many of them seem to know about the power required to drive their tools under varying conditions. How many builders can tell you the pressure on the tool for a given depth of cut; feed and speed for a given material on boring mills or lathes, yet how can they

expect to design the tool correctly for power and rigidity if they have not this information? Why is the "power limit" so ridiculously low on many of our small machines, the spindle speed and feeds out of all proportion for the work they are expected to do? The answer is easy, the question has never been attacked, by most manufacturers at least, by the methods so well exemplified in the Taylor-White process or the Jones ingot mold.

With a tool steel which can be counted upon to give certain results, it will be possible for the manufacturer to build machines on scientific principles, instead of guesswork; then it will be possible to work the tool to its highest efficiency, instead of finding the "power limit" far below the requirements, as is now so often the case.

I recall an experience we had a few weeks ago while investigating some small drill presses, purchased in order to complete an order containing several thousand duplicate cast iron parts. The ones finally obtained gave a maximum spindle speed of 290 revolutions. The Morse twist drill table calls for a speed of 214 revolutions per minute for a $\frac{5}{8}$-inch drill in cast iron. We ran the same size drill at 290 revolutions per minute passing through a 3-inch hub in one minute and twenty seconds. We found it paid to grind up completely two twist drills in a ten-hour day on each drill press; the tool room force of course keeping the men supplied with sharp drills.

It should be understood that the above twist drills were not treated, but the same as we have been using for years. If a $\frac{5}{8}$-inch drill on a 24-inch drill press can be run at the maximum speed and feed obtainable, how can we expect to run the smaller sizes efficiently, and what, I wonder, does the manufacturer expect one to use the speeds for, obtainable with the gears in? We have found it possible to double the speed of all our drill presses, but this, of course, does not help the feed.

From data obtained by Mr. Taylor, over a long period of years, it has been possible to obtain a relation between the circumferential speed, feed, depth of cut, and time element, and so derive an empirical formula, upon which data,

together with the details of any given tool, most ingenious slide rules have been formed. It is possible with these instruments (which are in practical use), to make out time cards from the blue-print and before any work has been done on the piece, showing the workman just where to put his belts and how to set his feeds and depth of cut for a given material in order to have the desired power, and at the same time remove the maximum poundage in order that the tool should last a certain pre-determined time. The time the tool should last being based on the time necessary to change the tool, and is expressed in the empirical formula above referred to. I merely mention the above facts to show how the tool designer of the future will be able to accumulate a store of information which will be the basis of all the work, and how widely the machine shop practice of the future will differ from that of the past.

"Production to the Power Limit" was the title of a most interesting article written over five years ago by Mr. Arnold, in which he strongly advocates pushing all tools to the limit of their endurance, on the principle that the quicker they are worn out, the more money they make. Although this view is now accepted by many leading machine shops, it has not been enforced, old tools which should have been scrapped years ago, being in operation. If Taylor-White process is introduced into shops of this character and worked to its very best advantage, the weaknesses of these tools will be developed at once, and they are bound to go where they belong, on the scrap pile. Probably you have all read Mr. Porter's article on, "The Radical Policy of Scrapping Expensive Machinery." This policy applies just as well to small machine tools. In the majority of our machine shops, where all of the tools are relatively small, there is just as big a field for this radical policy as in our largest establishments. The turret lathe, milling machine, gang drill, etc., are all coming into general use, and have resulted in the scrapping of many old style tools. The Taylor-White process of treating tool steel, in a like manner, will result in the scrapping of tons of stock, and just

as the last twenty years has seen the establishment of self, or air-hardening tools in all our shops, so in the next few years I think we can predict that all machine shops, who wish to keep to the front, will be using steel treated by the new process.

My remarks up to this point have dealt with the relative merits of tool steel, and the great increase in the output possible, when the Taylor-White process is used.

The question now arises, How are we to maintain this increased output throughout the shop? A person who has had little or nothing to do with machine shop management would probably think this an easy question, but it is, notwithstanding, a most difficult one. We must not judge the average conditions by those encountered in Philadelphia, where labor unions have but small control, but rather turn our attention abroad, or to our Western cities, to realize the difficulties encountered by the shop superintendent.

There is nothing new about driving machines to their power limit. I remember reading an article by Hiram Maxim on "Trade Unionism," where he quotes an old Scotch machinist, who told him when a boy, how to become a good machinist, namely, "to work the tool to the limit, to run on the belt, and always have a new tool ready to put in tool post, etc., etc." How closely is this policy followed out to-day by our workmen? The average foreman is far too busy following up orders, etc., to look after the details of speed on individual machines, and no one else is in close enough touch with the work to give it the required attention. The only satisfactory solution to the problem, where there are sufficient men to justify the move, is to appoint a speed foreman, who must be a man of considerable tact, in the beginning at least, in order to maintain the good will of the men.

Production to the "tool limit" is but one of the many means to attain the end that all up-to-date concerns have in view, namely, to produce a better article at a cheaper cost. It has been well named the age of "intensified production," and extends to every branch of manufacture. Competition has become so severe, unless one makes use of every opportunity, he is soon driven to the wall.

The engineer of the present day has before him a tremendous field, the production of the best for the least money, involving a thorough knowledge of every branch of engineering, shop management, etc. The laboring man cannot stop the advance any more now than he could in the past, but as he is just as much a part of the whole, as the machine or tool steel, he should be just as carefully watched, his welfare attended to, his physical and mental conditions looked after, and, in fact, be made just as good a workman as possible. In many establishments the machinery is most carefully attended to, while the man who operates it, the keynote of the whole scheme, is ignored. The importance of this fact is now being realized by many concerns, much money being spent, money which will pay big interest, to add to the comforts and welfare of the employees. It should be clearly understood that nothing is offered in the way of a bribe or obligation, the effort being to make the surroundings such that the workmen are both physically and mentally stronger, and in a position to turn out more work unconscious to themselves. Methods like these will, I think, help the labor troubles considerably and facilitate the introduction of new ideas.

Too much stress is placed on what a machinist is paid per hour, or how long he works by the time clock. These points are of but secondary consideration, the "work rate" being the true gauge.

At the Link-Belt Works no fixed rate of wages is employed, the men being paid according to their merits. After the introduction of Taylor-White steel, it was essential to remove the piece rates from many standard operations, and in all such cases the policy of the company has been to divide the savings effected with the men. After the men knew that they would share the advantages derived from the new process, their whole attitude was different, and, in fact, what else could we expect.

In the latter part of this paper I may have seemed to digress considerably from the matter in hand, but it all tends to show how far reaching are the influences of the Taylor-White process.

In conclusion I wish to state that it was due to the courtesy of Messrs. White and Taylor that I have been able to present to you this evening the statistics and steel chips obtained at the Bethlehem Steel Company.

COMMERCIAL ALUMINUM-ZINC ALLOYS.

No alloys containing more zinc than aluminum have any specially valuable mechanical properties, even the alloy of equal parts of both. The alloy Al—2, Zn—1, reaches a tensile strength of 40,000 pounds per square inch, melts at 425 degrees centigrade, does not easily oxidize, and takes a fine finish. It closely resembles a high-carbon steel in character, and is the hardest and strongest of the Al-Zn series. Its specific gravity is 3·8. A contraction of 17 per cent. takes place during alloying. The alloy Al—3, Zn—1, is the most generally useful of the series. It is softer than the last, tensile strength, 35,000. It is not malleable, but yet not brittle, bending before breaking. Hence, castings may be straightened out. Specific gravity 3·4, contraction 14 per cent.; good castings are yielded. When made from pure metals it is equal to finest brass in the lathe and under the drill and fire. Its color is equal to that of aluminum. It is used for scale beams, astronomical instruments, light machine parts, testing machines, surgical appliances, etc. Below 25 per cent. zinc the strengths of the alloys decrease rapidly. The 15 per cent. alloy can be rolled and drawn; tensile strength 22,330 pounds per square inch.—*The Electrochemist and Metallurgist.*

A NEW METHOD OF ADULTERATING WINE.

It has recently been ascertained that a peculiar method of wine adulteration has come extensively into vogue in European wine-growing countries, and which involves the conversion by chemical means of red, into white wines.

A French chemist, in the course of certain investigations upon the constituents of the ashes of certain wines, found present therein about one-half of 1 per cent. of manganese protoxide per liter of wine. Further investigation of the subject seems to have confirmed the suspicion that the investigator had to deal with a red wine which had been treated with animal charcoal (bone-black) and potassium permanganate for the purpose of effecting its decolorization. It also was shown that this artifice had assumed large proportions among the wine producers, since the public had begun to show a preference for white wines, which consequently had increased in price.

The following method of detecting this method of adulteration has been proposed. Ten cubic centimeters of white wine should be treated with 1 to 2 cubic centimetres of caustic soda solution, followed by 1 cubic centimeter of hydrogen dioxide. When these constituents are thoroughly mixed, the liquid will instantaneously take on a mahogany-red color. In the case that hydrogen dioxide is not available, the same reaction will occur, though more slowly, by using in excess of caustic soda. W.

THE FRANKLIN INSTITUTE.

Stated Meeting, held Wednesday, June 19, 1901.

OBSTRUCTIONS TO COMMERCE AND HOW TO REMOVE THEM.

BY LEWIS M. HAUPT, C. E.
Member of the Institute.

Commerce is the life of nations and water its principal medium of communication.

Ships are the shuttles and the ocean is the loom that weaves together the human family. Without them, portions of the earth would revert to barbarism.

The highest stages of civilization therefore demand the shortest, freest and most ample routes for commerce, but the general trend of the physical forces is toward the degradation of channels by the accumulations of detritus carried down the rivers or along the shores and deposited wherever the continuity of the stream is broken or diminished.

The mountainous tributaries with their steeper slopes carry their sediment to the main streams where the larger particles are deposited in the upper reaches, thus raising the flood plane as well as the bed of the river and building obstructing bars which must be removed by the application of science.

Although "all the rivers run into the sea, yet the sea is not full" because of those beneficient counter forces which return the waters unto the place from whence they came. There the mountains condense and reprecipitate them for a renewed attack upon the land.

Not so, however, with the eroded alluvium which is perpetually rolling down the incline to fill up the channels or deltas with dangerous obstructions.

The poet Milton has aptly said:

> "Accuse not Nature, she hath done her part,
> Do thou but thine."

But mind cannot dominate matter until it has first mastered her methods of operation. Man cannot change physical laws. He can merely apply them after observation and experience have demonstrated their properties. Although centuries of research have taught mankind something of these attributes, much yet remains to be discovered.

Analysis and synthesis are the handmaids of progress. Success is the climax of failures, while failures are the wrecks which serve as buoys to mark the channel to success.

Every sand bar is the effect of natural causes and it frequently possesses certain features, as to form, position, slopes, profile or magnitude which indicate the direction and nature of the forces operating to produce it, and which characteristics suggest the proper treatment for its removal.

Every break in an alluvial coast is obstructed by its submerged embankment or outer bar, either drift or delta, which rarely carries more than fifteen feet of depth at mean low water and which compels vessels to await high water and sometimes spring tides, involving delays of weeks and formerly of months, before being able to leave port with full cargoes.

Only last week, the 15th inst., the "Nordland" was obliged to leave 1,000 tons of freight on the dock at this port because of the limited draught in the channel, while vessels of 27 feet draught have declined to charter for Philadelphia.

The rise of the tide is, however, very variable, not only at one point, but at different points, depending on the configuration of the shore line. In some tideless seas it is zero, while in funnel-shaped estuaries it may oscillate as much as 60 feet. Around the British Isles the tides range from nothing at Courtown, Ireland, to 35 feet at St. Malo.

Along our Atlantic seaboard it ranges from about 2 to 10 feet, while in the Gulf its mean oscillation is only 14 inches. In the great inland seas of the Baltic and Mediterranean it is about 1 foot, so that there are many ports where additional depths must be provided to meet the growing demands of commerce.

Waves also constitute an obstruction when too tumul-

tuous, occasionally involving the loss of vessel, cargo and crew.

Although sand bars are the most general and most dangerous obstacles, because submerged, there are others which are quite as effective even though visible. These are the peninsulas, isthmuses and continents which intercept the trunk lines of trade and require large détours to be made, involving loss of revenue with no corresponding benefit.

The most striking example of this class of obstacles on the globe is the continent of South America, which lies east of the meridian of Charleston and therefore separates our Atlantic and Pacific coast trade by 15,000 miles more or less and requires the circumnavigation of the continent because of the Isthmian barrier. The piercing of this narrow strip of land by a deep-draught waterway would obliterate the continental obstruction and at the same time bring all the habitable sections of the earth into much closer contact, thus contributing more than by any other possible work to cement the nations of mankind and to advance civilization and Christianity.

Other lesser obstructions to our coastwise commerce are to be found in the Peninsula of Florida, the Maryland-Virginia Peninsula and those of New Jersey and Massachusetts; while the overland portages separating the Ohio River from Lake Erie and the Mississippi from Lake Michigan are barriers which demand and are receiving public attention.

The economic interests of this country will soon awaken to the necessity of systematically developing trunk line water routes extending from the Atlantic seaboard through the Great Lakes to the Mississippi and Gulf, and the development of an incomparable coastwise system of canals for our internal commerce. This is one of the factors which should be engrafted on the proposed new Department of Commerce and Public Works.

Another obstacle to the growth of commerce is tolls, and in this respect this city is particularly unfortunate in having three artificial waterways of limited capacity still main-

tained as toll gates, to levy tribute upon the raw materials required for her manufactures, while her channel to the sea is not yet sufficient to enable the deepest ocean liners to reach her wharves in safety, fully laden.

The price of coal or the absence of stations where it may be secured at any price, constitutes another impediment to the interchange of trade. This defect may be in part ameliorated by increasing the navigability of our rivers and the opening of their mouths for larger bulk movements and cheaper deliveries of this prime necessity at remote stations. A very large tonnage might be placed on the Pacific stations, from the Appalachian fields if the Isthmian canal were available, thus creating new markets. Such are some of the physical obstacles which it is the province of man to remove or reduce to their lowest terms, and it is important in this connection to trace briefly the efforts which have been made in this country to secure these results.

INTERNAL IMPROVEMENT DUE TO PRIVATE CAPITAL.

Our internal waterways and most of the railways of the past century were largely the product of private capital expended by corporations holding State charters. In this way the Dismal Swamp, the Union, James River and Kanawha, the Erie, the Delaware and Raritan, the Schuylkill Navigation, the Saint Mary's "Falls," the Louisville, the Hudson, the Juniata, the Illinois and Michigan, the Monongahela Navigation, and many other canals and waterways were built and a large traffic developed upon business principles. Many of these were subsequently acquired by the Government, and made free. Nearly the entire railroad mileage of the United States was constructed in the same way by private funds.

As early as 1790 Congress ratified certain State acts authorizing public improvements by private companies. In 1800 Georgia was authorized to collect a duty of 3 pence per ton for clearing the Savannah River. Two years later, $30,000 were applied to lighting the Delaware, and in 1806 funds for further improvements were authorized to be

collected by the Port Wardens of Philadelphia by levying a duty of 4 cents per ton on commerce.

In 1816 Virginia incorporated a company to improve the James River. On the admission of Alabama, in 1819, an act was passed authorizing the appropriation of 5 per cent. of the net proceeds of land sales for roads, canals and rivers. The first appropriation for the survey of the Mississippi River was $9,500, made in 1820.

In 1822 the Secretary of the Treasury was authorized to supervise the construction of a sea wall at Smutty Nose, and a breakwater in Delaware Bay.

The next year the authority to make surveys was vested in the President, and in 1824 his powers were extended to employ skillful civil engineers and to detail officers of the Corps of Engineers to make surveys "of such roads and canals as he may deem of national importance," and also to provide the necessary plant.

From 1826 to 1839, through the Adams and Jackson administrations, the policy of the Government was to collect all appropriations for public works affecting interstate commerce into general bills, but from the latter date until 1867 it was relegated chiefly to the States, with the exception of 1844 and 1852, when general bills were passed, the latter being for Western rivers. In 1867 the general bills were resumed, and have continued to be the recognized policy of the Government, although of late years it has been a difficult matter to pass the appropriations for rivers and harbors during the short sessions of Congress.

Thus has grown up the present system of detailing military engineers to conduct our public works and authorizing them to employ civil engineers as their assistants, subject to suspension in case of the failure of the bills.

Between 1822 and 1866 inclusive. the expenditures were .	$14,990,170
Between 1867 and 1900 inclusive, the expenditures were .	332,487,627
Making a total of	$347,477,797

Until recently it has been distributed very generally over disconnected improvements, and it may not be out of order to review some of these works with reference to their effects on commerce.

During this time a large amount of experience has been obtained, however, but its recipients are transferred under our system to other points where there may be no opportunity to apply the knowledge thus gained because of the different conditions prevailing.

The failure of the appropriations and the transient assignments of those in charge may therefore be regarded as additional obstructions to the securing of deep channels for our ships.

It should be observed, in passing, as a distinguished Senator recently remarked, that "the currents of the ocean depositing sand along the coast throughout the years and centuries pursued their way in defiance of our edicts and laws," thus showing the futility of human efforts to utilize physical forces when these latter are not fully understood.

The Senator recognized the fact that the bars are due to ocean currents, but this is not all; he might have added "wave action," angle of approach, configuration of shore line, tides, winds and many other elements which combine to make every inlet a special problem. For example, the ports of Charleston and Port Royal in South Carolina, although adjacent, are as dissimilar in topographic features and results as can well be imagined, and for good reasons. Charleston is an excellent type of a *drift and wave bar* formed from beach sand driven in a prevailing direction by the resultant of the dynamic forces of the sea and the main ship channel, across the bar, which is cut out by the ebb currents, is located about 7 miles south of the gorge or opening into the bay. The natural depths at this point were about 15 feet in 1777, and 12 feet a century later at mean low water, while at Port Royal they are over 21 feet, and the bar channel lies directly in front of the gorge, where it has remained for over 125 years without deterioration or protecting works.

SUBMERGED JETTIES.

In entering extensively into this class of work by the use of jetties, a Government officer formulated the conditions to be fulfilled in them in 1879 as follows:

(1) They should not impede the inflow to such an extent as to prevent the tidal basin being filled, as now at every influx of the tidal wave.

(2) They should control the outflow to such a degree and in such a manner that a channel of the required depth will be maintained through the bar.

(3) They should not to any considerable extent cause a movement seaward of the main body of the bar. In brief, the works should be designed to admit the flood tide freely, confine the ebb tide to a single channel and prevent bar advance.

To secure these effects it was recommended that two convergent jetties be built having their inner or shore ends submerged and their outer or bar ends built to high water, and the cost was estimated to vary from $1,800,000 to $3,000,000 for a 21-foot channel. The mode of construction was to be "very gradual in its progress, to admit of such modifications in the lengths and heights of the jetties as experience shall dictate."

"High-tide jetties are not recommended, as their effect would be to form new bars outside of the present one, requiring jetty extensions." These general conclusions were considered so sound that the works at numerous South Atlantic, Gulf and Pacific harbors were based upon the submerged jetty system, but one by one they have been abandoned and the jetties raised; first, to mean low water, then to mid-tide and finally to above high water, so that the Charleston entrance is the only extensive illustration remaining of this type of construction and it may be reviewed to advantage for its experience.*

Work on the jetties was begun in 1879, and in 1881 some experimental dredging was done on the bar, which was said to be so exceptionally hard that the cutters did not work, so it was abandoned and jetty work continued.

By 1888, or after nine years of "very gradual" progress and experiment, the greatest available depth between the jetties was but 11½ feet and the officer in charge recom-

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* See "Harbor Studies," Engineers' Club of Philadelphia, January, 1886.

mended a return to dredging at a cost of $100,000, as well as the building up of the jetties to a greater height. A Board of Engineers in reporting on this, suggested that "the two jetties should be brought to mean low water level." * * * "Above this * * * construction should take place tentatively." The height mentioned is merely for use as the basis of an estimate. The dredging of the main channel to a depth of 15 feet and 350 feet wide is recommended.

In 1890 it was stated that "the action of the jetties is to be assisted by dredging" and during the year 56,626 cubic yards were removed. This was followed in 1891 by the dredging of 47,626 yards. It was also estimated that if the jetties were brought up to 3 feet above low water, throughout, the cost would be $5,334,500. But what matters the cost if results are attained?

Up to June, 1891, over $1,800,000 had been expended in the thirteen years of work and a depth of 12 feet had not then been secured in the proposed new channel. After more than twenty years the report for 1900 states that the total cost to June 30, 1899, was $4,037,256.70 and that the channel depth was not less than 20 feet. The submerged jetties were completed in 1897. During the following year dredging was continued excepting for three months, while the dredge was being repaired. The depths varied from 19·3 feet to 20·1. The total amount of material removed that year was 253,401 cubic yards. A new and larger dredge was authorized, to cost not more than $150,000 and $60,000 was the estimated cost of maintenance. The map accompanying this report shows the crest of a new bar lying in the open ocean and about ¾ of a mile beyond the end of the completed jetties through which it is necessary to maintain a channel by dredging. It is therefore manifest that these submerged jetties have not fulfilled the requirements of scouring out and maintaining a channel, nor of preventing the seaward advance of the bar and that the expenditures and operations of the past twenty-two years have been beneficial mainly in the experience furnished, for if a channel is to be secured and maintained

by dredging in the open ocean, it would seem to have been better to have attacked the bar in its original position and to have saved the $4,000,000 put in the jetties.

Since the inauguration of the general bill for rivers and harbors in 1867 the amounts have increased rapidly from year to year until they have in themselves become an obstruction to commerce from their very magnitude, as was instanced at the close of the last session when the bill was "talked to death."

ANNUAL INCREASE OF EXPENSES.

Between 1867 and 1879 the total expenses were $53,763,-068·57, or about $4,480,000 per annum, while after the theory of the submerged jetty was extensively introduced and twin jetties were built under the tentative methods recommended the total expenditures have aggregated for rivers and harbors $278,724,558.64 up to and including 1900, or an average of about $12,670,000 per year.

The annual expenditures jumped from $3.791,000 in 1878 to over $8,267,000 the next year and have been increasing at a rapid ratio until they exceeded $20,000,000 in 1898, due in some measure to the increasing cost of maintenance on exposed bars by dredging. Although the total of nearly $350,000,000 expended since 1822 in this class of improvements may seem large, it is much less than that spent by countries which are smaller than the state of Texas, but their methods are such as to secure more permanent results. It will thus appear that our system is at fault and becomes, as has been stated already, an obstruction to commerce, since its very magnitude makes it a menace to the success of party control. At the last session of Congress it was stated that the patronage in the works recommended and in progress on the river and harbor bill amounted to about $300,000,000, thus placing the grave responsibility upon Congress of reducing it almost arbitrarily to some reasonable sum in order to maintain much needed channels to the sea. So much for the policy and various obstructions which have been suggested as impediments to our commercial development.

Let us now turn to a few illustrations of methods which have been applied to create open channels and note the results. The ordinary methods in vogue were by dredging; by hightide jetties in pairs; by submerged jetties and by a single jetty, to which may now be added the single, curved or "reaction breakwater" and the use of dynamite, without dredging or auxiliary works.

DREDGING.

At several points dredging has been relied upon to deepen the approaches to the ports. The most successful illustrations of this are at the Mersey Bar, Liverpool, and at Gedney's channel, New York. At Mobile, Pensacola, Southwest Pass and many other points it has not been so satisfactory, since the gain in depths have not been permanent and are expensive to maintain, as the following extracts from the official reports will show.

PENSACOLA HARBOR.

For many years Pensacola had a natural depth of 23 feet, which was greater than that of any of the Gulf ports. It was readily entered by sailing vessels, but the growth of the inner middle ground so reduced the channel depths that in 1881 a project was recommended for a cut 300 feet wide and 24 feet deep at low water, to be secured and maintained by dredging.

During the subsequent twelve years this depth was secured several times, but not the width. The report states: "The relief of the commerce of the port by dredging under this project, while it served a purpose, proved to be very unsatisfactory, as, owing to the conditions, mainly the location of the channel with reference to the middle ground, rapid and constant filling of the channel occurred."

In 1891 the project of 1881 was abandoned, and it was proposed to open a new channel across Caucus Shoals by means of jetties, and by dredging if necessary. In 1895 a special board was appointed to reconsider the plans of 1891. It adhered to the location of the 1891 channel. By this date the depth had shoaled to 21 feet. Another Board of

Revision recommended that a dredge be built, and that until a channel be opened by dredging, no jetties should be built for its maintenance.

In 1899 the plans were modified to provide for a 30-foot channel.

The instability of the dredged channel is well illustrated by the following tabulated statement taken from the official report of 1900:

Date.	Channel.		Cubic Yards Removed.	Remarks.
	Projected.	Secured.		
				Estimated cost, $150,000.
1881	24 x 300			Contract let at 40 cents per cubic yard.
1882–3			8,406	Contract let at 79$\frac{7}{10}$ cents per cubic yard.
1883–4			24,966	Dredge hire, $333.33 per day.
1884–5			53,369	
1885–6		24 x 120	55,355	
1891–2	26 x 300		14,151	
1893, Aug.		24 x 225		
1895, Dec.		21—		Dredged between October '95, July '96.
1895, Dec.		24 x 120		
1896, July	30 x 300	24 x 80		
1897, July		23·4 x 85	300,424	R. Moore dredged April 1897—July '97.
1898, Feb.		22·8 x 100	255,029	R. Moore dredged Feb. 1898—July 27, '98.
1898, July		24—		
1899, June		25 8—	334,405·5	R. Moore dredged Feb. 8, '99—June 30, '99.
1900, June		28 7—	479,087 9	R. Moore dredged during fiscal yr., 1900.

There were $215,000 appropriated between 1878 and 1886 at which date the estimated cost of completing the 24-foot channel was $40,000. The tides failed to maintain the dredged channel.

In 1888 it was stated that $60,000 would be required for completion, making the total cost of the work $275,000. This estimate was increased in 1890 by $81,000, bringing it up to $356,000.

In 1891 two jetties, 3,500 feet apart, were proposed at an estimated cost of $1,830,000, while the estimate for a 24-foot

channel by dredging was $190,oco, with $30,000 for maintenance. It was, therefore, recommended that dredging be continued.

In the 1900 report the available depth is given as 28·7 feet, although the central depth had been dredged to 31·2, showing a shoaling on this line of 2·5 feet, and on the range 75 feet east of this, the loss of depths was 4 feet; while on that 75 feet to the west it was 2 feet. To complete the project of 1891 would require the dredging of 350,000 cubic yards.

To secure 30 feet in front of the city would require the removal of 4,985,000 cubic yards, estimated, at 16 cents, to cost with incidentals $825,000 by contract; but it is recommended that the Government build a dredge and operate it by day's labor as "by far the most economical." The amount estimated for the completion of the existing project is $683,200.

The expenditures up to June 30, 1899, were	$547,161 32
The expenditures for the fiscal year 1900, were	98,846 64
	$646,007 96

On January 6, 1900, the dredging contract ceased with a depth of 31·2 feet, which had shoaled by June 30th to 28·7 feet.

These statements serve to illustrate the increasing costs of creating and the inability to maintain the requisite channels by dredging, for it appears that at no time has the full width been obtained, and that the depths, although occasionally exceeded, have rapidly shoaled to less than those desired for deep-draught vessels. The filling in 1900 was at the ratio of about 5 feet per annum along the axis of the cut, while the cost of the work was nearly $100,000, and yet about 480,000 cubic yards were dredged out. Still the channel is not self-sustaining. To maintain it would evidently require the removal of a much larger volume annually at increased cost, so that it would seem to be more nearly correct to figure upon over $100,000 per annum to keep the cut open to its full depth of 30 feet, independently of the width. This is $3,333,333, if capitalized at 3 per cent. It does not

give much promise as to economy nor guarantee as to permanency of channel dimensions. It is believed that a single jetty at this entrance would control the littoral drift and secure the channel at much less ultimate cost than by dredging.

A pilot of over thirty years' experience at this port stated that "there must be a breakwater to give direction to the current." To this all the pilots agree.

MOBILE HARBOR.

The importance of improving this port led to the appropriation of $10,000 as early as 1826 and additional amounts in subsequent years aggregating $207,000 up to 1869, when the State Legislature created a harbor commission and bonds were issued by Mobile County for the removal of obstructions. In 1872 a Government Board of Engineers decided that the plans proposed by the State Board would be detrimental to the work then in progress by the United States which was to dredge a channel 9 miles long and 13 feet deep from the inner harbor to the sea.

Various estimates were made as to the cost of creating the channel which ranged from $91,208 in 1866 to over $2,000,000 in 1878; the latter being for a channel 21 feet deep and 200 feet in width. The unit prices in 1870 were 50 cents per cubic yard and in 1875 they had dropped to 17.

In 1873 the State Board was abolished after expending $72,025.95. The Mobile Breakwater Company was chartered by the legislature and began operations in 1877, at which date there had been dredged from the channel 1,303,581 yards—at a total cost of $390,169.55. The dredging averaged 28 cents. By 1884 the cost had fallen to 9 cents per yard by contract.

Between February 19, 1881, and April 25, 1887, there were removed 5,973,919 cubic yards on the 17-foot project and it is reported that there has been a refilling "of about 1,300,000 yards or at an average rate of 216,660 cubic yards per year;" 700,000 yards then remained to be removed to complete the project, estimated to cost $84,000, but the channel was "altogether too narrow and should be widened

at least 100 feet, which will require the removal of 3,000,000 cubic yards at a cost of about $360,000." The progressive stages of the channel may be shown from the following extracts from the reports of the Chief of Engineers of 1900.

The first project for a 10-foot channel was covered by appropriation of $228,830.68 between 1826 and 1857.

The second project for a 13-foot depth and 300 feet wide, between 1870 and 1876 secured $401,000 from the Treasury.

The third, for a 17-foot channel 200 feet wide, covered the period from 1880 to 1888, when it was enlarged before completion to one 23 feet deep and. 280 feet wide. Between 1878 and 1886, $750,000 more were appropriated, and the fourth project, from 1888 to 1898, has secured $2,268,800 for dredging, while the fifth state of the improvement was begun June, 1899, and is now in progress under appropriations for continuing contracts of $600,000

Making the total appropriations from 1826 to date . . .	$4,248,630 68
While it is estimated that to complete, will cost	1,040,000 00
	$5,288,630 86

and it is said that at the beginning of the fiscal year 1899–00, there was a navigable channel of 19 to 22 feet, but available for vessels drawing 22·5 feet "on account of the softness of the material which had filled in." During the year 4,273,381 cubic yards were removed, resulting in a channel of from 40 to 150 feet wide "of over 12 miles dredged to a depth of 25 feet." The detailed report states that the condition of the channel on June 30, 1900, showed 14 miles having less than 23 feet; 12 miles having less than 22 feet, 10·5 miles with less than 21 feet and 2 miles of less than 20 feet.

From this it would appear that although over 12 miles were dredged to 25 feet it has all shoaled to 22 feet and a portion of it to 19 feet. This constant tendency to shoal is further illustrated by the previous reports, for in 1893, the central depth was dredged to 23·86 feet, but shoaled to 19·6 feet; in 1894, it was dredged to 25·2 feet, but shoaled to 19·6 feet; in 1895, it was dredged to 26·5 feet, but shoaled to 23·5 feet; in 1896, the contract was reported completed, depth,

23·0; but by 1897 considerable fill had taken place and 20 miles of the channel had less than the contract depth. Sixty thousand dollars were appropriated for maintenance with resulting depths of 20 to 23 feet, with subsequent further filling to reduce depths to 20 to 22·5 feet and $100,000 more applied to maintenance with a renewal of the continuing appropriation.

From the above condensation it would seem that the annual expenditure of $60,000 is insufficient to maintain the 23-foot channel, about 33 miles in length, through Mobile Bay and that measures should be taken to protect the cut from the drift by some permanent regulating works. If it should cost $100,000 a year to maintain a channel, it would no doubt be expedient to expend $2,000,000 in protection work to make it more permanent. It seems hardly necessary to add that this mobile material, with its suggestive name, is dumped into a mobile bay to be carried by the automobile tides and winds back into the Mobile channel.

It is suggestive of Tennyson's "brook" which "goes on forever."

THE TWIN JETTIES SYSTEM.

One of the most suggestive examples of the effort to secure depths by two jetties, is that at Galveston, on the Gulf coast, where various plans were tried and modified from time to time. Here, however, the largely increased cost is found to be due to the rapid advance of the bar gulfward, in consequence of the building of the leeward jetty first, after the gabionades used for the windward or north jetty had been found useless and abandoned. This instructive experience is best stated by extracts from the official reports as follows:

"On the north side of the island in front of the city of Galveston, depths of 35 feet are found in a narrow channel. This area of 270 acres forms Galveston Harbor."*

Access to it was obstructed by an outer bar whose crest, in 1869, was about 3 miles from the inlet and whose low

* See report of a Board of U. S. Engineers, January 21, 1886.

water depth was about 12 feet. An inner bar also existed, having depths varying from 9½ to 15 feet.

To remove this the city of Galveston constructed a wooden jetty nearly a mile in length, in 1870, which maintained the depth so long as it lasted, but between the teredo and storms, it was of few years' duration.

The Government project for a 12-foot navigation estimated to cost $1,300,000, by two jetties, was not adopted. The first appropriation of $25,000 was made July 11, 1870, followed by one of $20,000 the next year, to dredge a channel 80 feet wide and 12 feet deep, across the inner bar.

In the year 1871, the officer in charge reported, "the work is not susceptible of permanent completion," and on July 20, 1872, that the dredger and plant "were not needed or worked during the year, due to the good effect produced by the jetty constructed by the city of Galveston."

In 1874, a board of engineers recommended a plan of two parallel and submerged jetties extending outward into the Gulf, over 2¼ miles apart and having a total length of 37,000 feet, or over 7 miles; estimated to cost $1,759,401.85, but work was delayed until April 14, 1877, when the north jetty, built of gabions, was commenced and by January 1, 1880, it was placed for nearly 2 miles. An examination made that year revealed the astounding fact that "the gabionade had essentially gone down below the original bottom, consequently it could not serve to direct or confine the currents."

These gabions, which were 6 feet high, were found standing in a trench from 4 to 7 feet deep and "contrary to expectations, they did not become covered with sand, but remained standing in a trench entirely uncovered."

This result was due to the fact of their being submerged and hence subject to cross-currents and overfall from both flood and ebb tides. It ultimately led to the raising of the jetties to above high water and the substitution of rip-rap of stone covered with heavy blocks, as well as other revisions of plans which it was stated offered "every guarantee of success."* At that date, 1880, the report says: "The

* Report of Chief of Engineers, 1880, p. 1205.

suggestion as to details of construction are tentative only." * * * "The south jetty should incline more to the north so as to contract the opening between the two at their outer ends, but still remaining more than 2 miles apart." * * * "It has always been assumed that the Galveston jetties are to be submerged, but to what depth can only be determined by results. * * * Should an average height of 5 feet above the sand bottom prove sufficient, it seems probable they can be constructed for $40 per lineal foot." The estimated cost for a 25 foot channel by jetties was then $1,825,813, yet nearly $9,000,000 have been expended to date. Under this revised project the work on the buried north jetty was discontinued and that on the submerged south jetty pushed as rapidly as possible, so that by June 20, 1882, nearly 4 miles were laid on the bottom and 2 miles of the second course was in place. It was then reported that the results were not such as were to be expected and the depth on the bar was 11½ feet, while there was a rapid advance of the bar gulfward.

The report of 1884 says, no benefit has resulted as yet to navigation and the outer bar movement still continues. Channels dredged on the bar are rapidly filled up by the drift of sand from the north. "The north jetty is absolutely required if it is expected to secure deep water." The civil assistant engineer reiterated this recommendation in his successive reports, until he was surprised to find himself relieved by orders from Washington without stating the cause.

The appropriation bill having failed in 1883, the city of Galveston again came to the rescue by subscribing $100,000 to continue work, and requested Captain Eads to submit a guaranteed proposition to create a deep channel, which he did at an estimated cost of $7,750,000 for 30 feet depth. His efforts to secure this contract, however, were unavailing, as it was represented that under Government control and the expenditure of $700,000, material increase in depths, amounting probably to 5 or 6 feet, could be obtained in two seasons. Experiments were, therefore, continued, and after building several miles of extra jetty work, made necessary by the

advance of the bar, without improved depths, the plans were again revised; the high stone jetties suggested by Eads were adopted, and the estimates raised to $7,00,000, "provided the money is freely supplied;" but still the jetties were to be 7,000 feet apart at their outer ends, and not as Captain Eads had proposed, "not over 2,000 feet." Work on the south jetty was continued, notwithstanding the frequent warnings and reports upon the injuries resulting from its extension.

In 1889 the writer urged upon Congress the necessity of building a north jetty, but in vain. Up to June 30, 1892, the south jetty had been extended about 5 miles (26,923 feet), and was "then within 5,400 feet of the outer 12-foot contour." A survey showed a depth of 13¼ feet at mean low tide in the outer bar channel. By June 30, 1893, the jetty reached the crest of the outer bar, after being extended 8,000 feet. This would make the bar advance over a half mile during the year. The north jetty was not commenced until April, 1893, so that the drifting sands were allowed to dam up the channel by the jetty placed to leeward, and to feed the bar, pushing it seaward and adding greatly to the length and expense of the work, with no increase of bar depths.

No sooner was the north jetty started than improved depths were manifest; for the survey of June, 1893, showed 14 feet, an increase of 9 inches with only about 1,500 feet of jetty completed and 2,100 feet of sill or uncompleted work. Thus the predictions and recommendations of the assistant engineer as to the utility of the north jetty placed to windward of the channel were immediately verified. The appropriations to 1893 were $4,828,000, and the gain in depth 2 feet in the twenty-four years.

The report for 1895 states that up to June 30th the north jetty had been advanced to a total length of 22,500 feet, or over 4 miles, and that it was 4,900 feet further to the 30-foot outer contour. Also, "that a marked change has taken place in the outer bar due to the rapid extension of the north jetty. The 12-foot contour has entirely disappeared, the inner 18-foot curve has advanced 5,400 feet into

the Gulf, while the corresponding advance of the outer 18-foot curve has been 1,800 feet."

The new channel has a least depth of $17\frac{3}{4}$ feet, where last year the depth was $12\frac{3}{4}$ feet, a gain of 5 feet in 12 months. The southeast channel deepened $1\frac{3}{4}$ feet during the year.

This gain of 5 feet is explained in another part of the report, where it is stated that "Dredging was commenced on April 11, 1895, and up to the close of the year (June 30th, ten weeks) 68,071 cubic yards of material had been removed." so that it is not correct to infer that the deepening was due to the scour of the tides as might be implied, but to the interception of the drift by the north jetty and the removal by the dredge of a part of the bar deposit, which was not permanent, since no channel exists in this locality to-day. Thus a quarter of a century had passed in experimenting with gabionades, low or submerged jetties located too far apart, a high-tide jetty built on the wrong side of the channel, and finally two high jetties still too remote to produce scour, until at last the one placed to windward of the channel arrested the sand movements, in part, and enabled the dredges to deepen temporarily the cut across the bar. The position of this new artificial channel is not fixed nor is it straight, as was expected, but in consequence of the constant wave action on the outer slope of the bar, it is being driven to leeward and crosses the line of the south jetty produced, making a curved channel in conformity with the law of currents in the open sea.

It merely remains to state in summing up this instructive example, that in 1900 it was reported that the

"South jetty was considered to have been complete

on February 14, 1897, when it was	35,603 feet long,
and the north jetty on January 29, 1898	25,907 " "
making a total length of	61,510 " "

or 11·65 miles, at a cost of \$8,251,156, or \$134 per lineal foot of jetty (\$717,500 per mile);" and of these $11\frac{1}{2}$ miles, it is believed by the writer that under the original condition of the bar 8 miles could have been dispensed with at a saving of nearly \$5,000,000 and with far better results.

The jetties have not secured the channel by tidal scour,

but the increased depths have been obtained by the aid of hydraulic dredging and the interception of the drift. During the year (1899-1900) 164,776 cubic yards were removed from the outer and inner bar channel. The total cost to June 30, 1900, is reported to be $8,385,079.11 and $50,000 is recommended for maintenance.*

CUMBERLAND SOUND.

The most pronounced failure to secure results by a pair of jetties, however, is that at Cumberland Sound, Ga., where the prevailing littoral drift is to the southward and where the first jetty was built on the south or far side of the channel, thus damming it up by the intercepted sand and pushing the bar to sea. At a later day a north jetty was partially built, but the two resulted in so complete a closure of the entrance that an emergency appropriation was made by

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* Local engineers in charge of operations:

Major	M. D. McAlester	1868
"	C. W. Howell	1871–'80
"	M. S. Mansfield	1880–'86
"	O. H. Ernst	1886–'90
"	C. J. Allen	1890–'93
"	A. M. Miller	1893–'97
"	J. B. Quinn	1897–'98
"	C. S. Riché	1898

Total appropriation to January 30, 1892,	$2,712,843
Additional Galveston,	100,000
Depth 13¼ feet	$2,812,843

(Total January 30, 1898, $8,251,166.47)
(Total January 30, 1900, 8,385,079.00)

BOARDS OF ENGINEERS.

1874 (p. 730) Gen. Z. B. Tower, H. G. Wright, Jno. Newton, Gabions.
1879 " " Jno. Newton, Q. A. Gillmore, Mattress
1880 (1221) " " " " " " Stone or concrete.
1886 (1297) Col. Duane, H. L. Abbot, C. B. Comstock, built up jetties and dredging.
1889 H. M. Robert, Gillespie and J. A. Smith, deep-water harbor.

Average expenditure for maintenance between 1897–1900 $157,905 per annum, since the jetties were reported as completed. This sum capitalized at 3 per cent. would represent $5,263,500 which would be more than double the cost of the single curved breakwater recommended by the civil assistant engineer Mr. Ripley in 1883.

Congress to remove the obstructions to commerce. This was after about 20 years of experiment and the appropriation of $1,787,500. In fact the channel was driven across the south jetty and it became necessary to remove a part of the same to admit light draught vessels and to dredge on the outer bar to keep it open. The crossing is now about a half mile south of the south jetty, while large sums are being expended on these obstructions to bring them to high water instead of improving the present inadequate channel which could be done quite reasonably.

THE REACTION BREAKWATER.

After prolonged research as to the action of the natural forces in building bars and maintaining channels a system has been evolved whereby the natural agencies might be employed to deepen the water by confining the ebb discharge to a limited section of the bar from which the drifting sand is excluded by an impassable barrier of such form as to cause the currents to scour by reaction. This method has been sufficiently demonstrated by the partial construction of a breakwater, detached from the shore at Aransas Pass, Texas, where the feeble tides of only about 14 inches have steadily increased the depth from about 6 to 15 feet in the shallowest part of the bar and to 25 feet and over along that portion which was protected by the completed part of the structure. This was secured without dredging and at a cost of about one-eighth of the estimated expense of obtaining a 20-foot channel by two jetties and dredging. As these facts are officially reported as to cost and results they indicate that under these unusually unfavorable circumstances the method has been thus far signally successful, yet although it has been submitted to the Executive Department of the Government having sole jurisdiction over this class of improvements, at numerous times during the past fourteen years it has invariably been rejected as of "no value," * * * "purely theoretical," * * * "fallacious," * * * "fatally defective," * * * or "lacking in novelty;" and although the work done at Aransas Pass has been accepted by the Government, after

being condemned as valueless, it is now proposed to embody it in the twin jetty plan as a substantial part thereof without compensation. This change would prevent the completion of the demonstration of its efficiency and compel the Government to secure the channel by recourse to dredging with constant expense for maintenance,—all of which are unnecessary and will prove injurious to this tidal entrance.

The creation and maintenance of an *esprit de corps* may be both useful and valuable to its members, but if it should be carried so far as to condemn and obliterate a system of improvements which experience has thus far demonstrated to be a complete success in solving the problem of creating and maintaining adequate commercial channels at a minimum cost, it would then become an obstruction to commerce and should be restricted to its normal service of military operation, for which the training at West Point is eminently adapted.

THE GREATEST POWER STATION.

Scientific American gives the following data respecting the equipment of the new electrical plant now in course of erection by the Metropolitan Elevated Railway of New York, viz.:

* * * * *

"The great power house, 200 feet in width by 400 feet in length, will be the largest in existence, and its compound engines will, we believe, without exception, be the largest single steam units to be found anywhere in service on land. The normal capacity of the power station will be 65,000 horse-power, and the maximum capacity about 100,000 horse-power. The steam plant will be made up of eight compound engines, which will be capable of running under a continuous load of 12,000 horse-power each. These engines are of an entirely new type, and they are placed in pairs on each end of a shaft which carries a Westinghouse generator with a revolving field 32 feet in diameter and weighing 185 tons. The chief novelty of the engines consists in the fact that the high and low pressure cylinders are placed at 90°, the high-pressure being horizontal and the low-pressure vertical. As there are two engines to each shaft, the turning moment is perfectly even, so much so that the customary flywheel is dispensed with, its place being taken by the heavy revolving field of the generator. The high-pressure cylinders are 44 inches and the low-pressure cylinders 60 inches in diameter, the common stroke being 88 inches. To find engines that will compare with these in size, we must refer to the engine rooms of some of the largest ocean steamships. The most powerful marine engines are those of the "Deutschland;" each quadruple expansion engine on this ship has indicated in twenty-four hours as high as 18,500 horse-power, or 50 per cent. more than the maximum capacity of the engines above described."

ELECTRICAL SECTION.

Stated Meeting, held Thursday, March 21, 1901.

SECONDARY REACTIONS IN ELECTROLYSIS.

By Prof. Joseph W. Richards,
Member of the Institute.

To be a thorough electrochemist or electrometallurgist, one should understand thoroughly electrolysis, and this is best attained by a study of secondary reactions.

To understand secondary reactions thoroughly, requires a considerable knowledge of chemistry. For this study, it is better that the student should approach it from the chemical side; that he be primarily a chemist who has added to his chemistry a knowledge of electricity, rather than the reverse.

Very, very much is unknown in this field. Some of the best known phenomena are differently explained by careful reasoners, and very little is so firmly established as to be even reasonably safe from overthrow. Many phenomena classed by one as secondary are referred to by another as primary, and *vice versa*.

The main object of this paper will be to state some of the laws of primary electrolysis and secondary reactions, and then to attempt a classification of the latter and to discuss several examples under each heading, by way of illustration and suggestion.

Using Faraday's notation throughout, I would offer the following definitions:

Primary electrolysis is the action of the current whereby it directs the ions towards the electrodes and liberates them *as ions* at the electrodes.

Secondary reactions are such reactions of the ions upon themselves, the electrodes or the electrolyte, whereby substances other than the ions come into existence at the electrodes.

The rate at which primary electrolysis takes place is

largely dependent, in solution, on the rate of diffusion in the solvent of the substance being decomposed. The rate at which secondary reactions upon the electrolyte can occur is similarly largely dependent on the rate of diffusion of the secondary products in the solution.

The work done during electrolysis is of two kinds; first, the work done in overcoming the ohmic resistance of the bath; second, the work done which is rendered latent as chemical energy. To these might be added the energy concerned in the Peltier effect, but this is in general so small, and known accurately in such a small number of cases, that I have omitted it from the subsequent discussion.

If we let R^c be the ohmic resistance of the electrolyte, that is, the resistance of the electrolyte as measured with an alternating current, and V^c the voltage necessary to overcome this resistance, for any number of ampères A, then

$$V^c = R^c \times A$$

If we call V^d the voltage necessary to furnish the energy rendered latent as chemical energy, we then have

total voltage $= V = V^c + V^d = (R^c \times A) + V^d.$

and the total energy required in watts, is

$$W = V \times A.$$

of which $V^c \times A$

appears as heat in the electrolyte

and $V^d \times A$

is rendered latent as chemical energy.

The energy which is rendered latent as chemical energy includes not only the chemical energy expended in the primary electrolysis, but also the energy expended in secondary reactions. That expended in primary electrolysis is positive, in the case of exothermic compounds, and may be negative when endothermic compounds are decomposed. The energy of the secondary reactions, that is, their algebraic sum, is usually positive, and hence usually assists the current instead of calling upon it for energy; in some few

cases this energy is negative, absorbing heat, and in these cases the current is called upon to supply the deficit. The point of first importance is that the energy of the secondary reactions forms an integral part of the energy of the circuit, and must be reckoned with just as strictly as the energy required for the primary decomposition of the electrolyte. The total chemical work of the current is represented by that required to transform the ingredients of the electrolyte into the compounds or substances which come into existence at the electrodes, whether of primary or of secondary origin.

Experimental determination of V^c *and* V^d.—An approximate determination of these important factors may be readily obtained during electrolysis. The former varies directly as the number of ampères passing, whereas the latter is independent of the current strength. If we therefore take two readings of the total voltage, V and V', with different strengths of current, A and A', the difference in voltage divided by the difference in ampères is R^c. We then have

$$V = V^c + V^d \text{ at } A \text{ ampères.}$$
$$V' = V'^c + V^d \text{ at } A' \quad \text{"}$$
$$\frac{V' - V}{A' - A} = R^c = \frac{V^c}{A} = \frac{V'^c}{A'}$$

Therefore $\quad V^c = R^c\,A \text{ or } V'^c = R^c\,A'$

and $\quad V^d = V - V^c \text{ or } V^d = V' - V'^c.$

The latter item, V^d, may also be observed experimentally by breaking the circuit and reading the back electromotive force. It falls usually very rapidly and so is difficult to obtain in this way. It is most satisfactorily observed in storage cells.

Calculation of V^c *and* V^d.—If we know the specific resistance of the electrolyte in ohms under the condition of the experiment, then R^c can be calculated from the size of the electrodes and their distance apart. Thus, let R be the specific resistance, then

$$R^c = \frac{R \times \text{distance apart in c.m.}}{\text{area in sq. c.m.}}$$

and, in any case

$$V^c = R^c \times A.$$

Subtracting V^c from the total voltage V, gives V^d.

In almost all electrolytes, R^c and consequently V^c decrease with rise of temperature and increased strength of solution.

The voltage lost in doing chemical work can be calculated when all the chemical changes taking place are known and their thermal value can be obtained in thermo-chemical tables. For a simple reaction, like the decomposition of melted caustic soda, NaOH, into melted Na and gaseous H at the cathode and O at the anode, it will suffice to know the heat of combination of melted Na, gaseous H and O to melted NaOH—all at say 216° C. If this is given in the tables, or can be calculated from the data given in the tables, then, calling this quantity Q, the heat energy furnished for one chemical equivalent of oxygen liberated is

$$\frac{Q}{2}$$

and the voltage absorbed in decomposition is

$$V^d = \frac{Q}{2 \times 23040}$$

In general, if Q is the heat of change of the final products to their state in the electrolyte, expressed per single chemical equivalent of oxygen liberated, then

$$V^d = \frac{Q_1}{23040}$$

It should be borne in mind that Q_1, and consequently V^d is determined only for the ingredients and products in certain definite physical states, at a given temperature, usually 15° C. and at normal atmospheric pressure.

For instance, if H_2 and O unite at normal temperature and pressure to liquid H_2O, evolving 69,000 calories, then

$$V^d = \frac{69{,}000}{2 \times 23{,}040} = 1{\cdot}50 \text{ volts.}$$

But H^2 and O at normal temperature, but at 10 atmospheres pressure would evolve 69,000 calories plus the work which

had been done in compressing them, which is 2,437 calories. Then

$$V^d = \frac{69{,}000 + 1{,}261}{2 \times 23{,}040} = 1{\cdot}53 \text{ volts.}$$

In other words, to decompose liquid water at 15° to hydrogen and oxygen at normal pressure requires $V^d = 1{\cdot}50$; but to do the same thing at 10 atmospheres pressure would require 1·53 volts. At 1000 atmospheres, the figure becomes 1·68 volts; while under an air pump, at 13 millimetres pressure, it sinks to 1·48 volts.

As to temperature, the above figure, 69,000, is good only at the temperature named, 15°, and for the gases at standard pressure uniting to *liquid* water at that temperature. The heat of combination at say 65° is different. It will be obtained by adding to 69,000 the heat necessary to warm the H_2 and O, at constant pressure, to 65°, and subtracting the heat given out by the H_2O falling from 65° to 15°. These amounts would be:

$$\left.\begin{array}{l}\text{To raise } H_2\ (65 - 15) \times 6{\cdot}82 = 341{\cdot}0 \\ \text{To raise } O\ \ (65 - 15) \times 3{\cdot}41 = 170{\cdot}5\end{array}\right\} 511{\cdot}4$$

$$\text{Evolved by } H_2O\ (65 - 15) \times 18.3 = 915.$$

whence

$$\text{Heat of combination at } 65° = 69{,}000 + 511{\cdot}5 - 915$$
$$= 68{,}596.5$$

and

$$V^d \text{ (at } 65°) = \frac{68{,}596{\cdot}5}{2 + 23040} = 1{\cdot}49 \text{ volts.}$$

In general we may then say, that the heat of formation of any product at any temperature is equal to its heat of formation at ordinary temperature, *plus* the heat necessary to raise its constituents from one temperature to the other (including in this any heat rendered latent by changes of state), and *minus* the heat necessary to raise the compound itself from one temperature to the other (including similarly any heat rendered latent by physical changes).

Having, then, the heat of combination at ordinary temperatures, the specific heats of the ingredients and of their

products, also their latent heats at critical points, we are then able to calculate the heat of formation at any temperature to which our thermal data extend, and thence to derive the voltage of decomposition at that temperature.

Another factor which may exert considerable influence on the voltage of decomposition of salts in aqueous solutions is the question of the dilution of the solution. This is a point often overlooked. The heat of solution of salts usually increases the greater the amount of water they are dissolved in; whence it follows that a greater voltage will be required for decomposition, V^d, for a salt in dilute solution (independent of any increase in V^c because of the poor conductivity of the weak solution.) If we should electrolyze zinc sulphate solution, endeavoring to precipitate all the zinc, the voltage of decomposition would increase slightly towards the end, as the last of the zinc was thrown out of the more dilute solution.

The next point to be considered, before classifying secondary reactions, is what the ions are in general.

For this information we rest almost altogether on the modern school of physical chemistry, Hittorf's researches being the pioneers. In the case of binary compounds, the basic ions appear at the cathode, the acid ions at the anode. In the case of ternary salts, the base appears at the cathode, the acid radical at the anode. Hittorf's researches were particularly illuminating, in showing the method of decomposition in salts of metallic acids, such as potassium chloroplatinate, sodium auro-cyanide.

SECONDARY REACTIONS.

I. The ions polymerize into more complex forms.
II. The ions decompose or dissociate into simpler forms.
III. The ions react upon the electrodes.
IV. The ions react upon the electrolyte.

I.

When the ions are simple, *i. e.*, composed of only one element, they are very probably atoms of that element. They can, therefore, either liberate the element simply as a

monatomic gas, or by polymerization as a more complex gas, liquid or solid—items depending mostly on the prevailing conditions of temperature and pressure, and possibly on the current density, *i. e.*, on the velocity with which the atoms are brought to the electrodes.

If fused mercurous chloride is electrolyzed above 350°, the mercury atoms will be liberated in the state of free atoms, as mercury vapor. Similar phenomena occur when melted sodium, potassium, zinc or cadmium compounds are electrolyzed at temperatures above the boiling points of the respective metals. Zinc iodide, at a high temperature, would give zinc vapor and iodine vapor both in the atomic state. It is only such rare cases that can be strictly regarded as instances of electrolysis without secondary reactions.

In almost all other cases of electrolysis the ions are not set free as atoms, but frequently polymerize to more complex forms, giving us the elements in their more usual molecular states. Molten sodium chloride at high temperatures furnishes monatomic sodium vapor and monatomic chlorine gas (Cl); at temperatures below 1200° monatomic sodium and diatomic chlorine gas (Cl_2). The voltage absorbed in decomposition would be less in the latter case than in the former, because heat is evolved when 2Cl passes into Cl_2 (quantity unknown). In the electrolysis of potassium iodide, if performed above 1500°, the iodine would be evolved as I, without polymerization, if below 1500°, as I_2. The change 2I to I_2 evolves 28,500 calories (Boltzmann). The voltage absorbed in decomposition would, therefore, be less in the latter case than in the former by the quantity

$$\frac{28,300}{2 \times 23,040} = 0{\cdot}62 \text{ volts.}$$

If potassium sulphide were electrolyzed above 1000°, the potassium would be evolved as monatomic vapor, while the sulphur atoms would unite or polymerize to S_2 vapor. Between 800° and 720° the potassium would escape as before, but the sulphur vapor would partly polymerize to S_6, and the voltage of decomposition be diminished. Between 710°

and 450° the potassium would polymerize to liquid metal, giving out thereby its latent heat of vaporization, and diminishing by just so much the heat absorbed in decomposition, compared with the higher temperatures. Between 500° and 450° the sulphur would evolve entirely as S_6. Below 450° the sulphur would polymerize to liquid sulphur, instead of gaseous S_6, and diminish the heat requirement by its latent heat of vaporization, a quantity not yet determined.

When water is electrolyzed under ordinary conditions, the H and O ions polymerize to H_2 and O_2 gas, and the voltage absorbed in decomposition, as calculated from the heat of union of H_2 and O_2 gas, is about 1·5 volts. At low temperatures, however, as much as 10 per cent. of the O atoms will polymerize to ozone molecules O_2. We do not know the heat evolved in 2H polymerizing to H_2 or 2O to O_2, or 3O to O_3, but we do know the value of the change from O_2 to O_3, which is

$$3O_2 = 2O_3 \text{ evolves } 72{,}000 \text{ çalories.}$$

It thence follows that if the polymerization into ozone were complete, the voltage absorbed in decomposition would be less than that in the case of O_2 being evolved, by the quantity

$$\frac{72{,}000}{6 \times 23040} = 0{\cdot}52 \text{ volts.}$$

In general the deposition of most metals and evolution of most gases involves the unknown heat of polymerization, from simple ionic atoms to the given molecular state, and we must content ourselves in the majority of cases with calculating the heats of formation for these bodies in the state in which they appear, which practically suffices, but scientifically is not so interesting as if we could analyze thermally all the different steps of the primary and secondary reactions.

II.

The dissociation of the ions into simpler forms is a phenomenon which occurs only with compound ions, *i. e.*, with radicals.

The general principle is that whenever the radical ion is not a chemical compound capable of existence at the prevailing temperature and pressure, then it must necessarily split up into chemical compounds which are capable or possible of existence.

Instances are numerous. The SO_4 radical from sulphates splits up into SO_3 and O, because there is no such chemical compound as SO_4.

$2NO_3$	from nitrates	splits into	N_2O_4 and O_2
$2P_2O_8$	" phosphates	" "	$2P_2O_5$ " $2O_3$
$PtCl_6$	" chloro-platinates	" "	$PtCl_4$ " Cl_2
$Au(CN)_2$	from auro-cyanides	" "	AuCN and CN
$2Al_2O_4$	" aluminates	" "	$2Al_2O_3$ " O_2
$2CrO_4$	" chromates	" "	$2CrO_3$ " O_2

Instances could be supplied at great length. The general tendency is for the radical to set free a minimum quantity of its acid ingredient, like O^2, Cl^2 or CN, and to leave the maximum quantity still in combination, forming the compound containing the largest possible quantity of acid ingredient; or, in some cases, the compound having the greatest heat of formation, so that the heat absorbed in the splitting up is a minimum.

We have no thermal data to apply to the successive steps in such secondary reactions, because the ion radicals are, by assumption, impossible chemical compounds.

It will be apropos here to make a general remark on the chemical nature of the liberated ions.

The cathions are the electro-positive ingredient of the electrolyte; they are chemically called the bases. They are always nearer to the metal or basic element, in composition, than is the electrolyte. If they react upon the electrodes or electrolyte their action is, in general, reducing; that is, they tend to bring elements out of combination towards the elemental state. Exceptionally, they act weakly in the opposite direction.

The anions are the electro-negative ingredients of the electrolyte; they are chemically acid elements or acid radicals. They are further removed from the electrolyte in *acid* character. If they react upon the electrodes or electrolyte

their action is, in general, the opposite of reducing, it is acidifying, tending to take compounds into higher states of combination. This influence is generally called in chemistry "oxidizing," because it so generally takes the form of higher oxidation; but the term is often misleading when applied to all these phenomena, and I much prefer to say "acidify ing," or, to coin a new term, "*perducing*." This latter term is not at present an accepted one in chemistry, but its meaning is so clear—the reverse of *reducing*—that I strongly commend its adoption. It would be a term to cover what is now meant by oxidation in its general sense, whether oxygen be present or not.

III.

REACTIONS OF THE IONS UPON THE ELECTRODES.

A. At the anode.

B. At the cathode.

In either case the electrode may be a solid or a liquid, and the product may be

(*a*) A gas, soluble or not, in the electrolyte.

(*b*) A liquid, miscible or not with the electrolyte.

(*c*) A solid, soluble or not in the electrolyte.

A. (*a*) The reaction of the anion upon the anode, forming a gas, is a common secondary reaction, especially where carbon anodes are used in baths containing oxygen com pounds. Such cases occur in the Hall process for producing aluminium, and in the fused-salt battery cells which use fused nitrates and a carbon pole. This latter reaction has been often proposed and investigated as a possible method of converting the energy of oxidation of carbon directly into electrical energy, and if a fused salt can be found which rapidly oxidizes at one temperature and is rapidly deoxidized by carbon at another, the problem may find some day a solution. The energy thus rendered available, would, however, be only that of oxidation to carbonic oxide.

Melted potassium chlorate splits up spontaneously at a red heat into chloride and oxygen, liberating thereby considerable heat. If poles of platinum and carbon are im-

mersed in the melted salt, the reaction will be explosive in its character, for the decomposing tendency of the salt alone is augmented by the heat of combination of oxygen with the carbon.

In the production of aluminium, by electrolyzing alumina in solution with carbon anodes, the oxygen burns the carbon to carbonic oxide gas.

Primary $Al_2O_3 = 2 \overset{+}{Al} + 3 \overset{-}{O}$.
Secondary, at cathode, x Al polymerizes to liquid aluminium.
" " anode, $3 O + 3 C = 3 CO$.

This reaction at the anode evolves heat, and therefore lowers the voltage of decomposition.

We have (CO) = 29,160 calories at 15°.
or, by calculation, = 30,367 " " 1000°.

$$\text{Whence, lowering of } V^d = \frac{30{,}367}{2 \times 23{,}040} = 0{\cdot}66 \text{ volt.}$$

A. (*b*) In refining any metal by electrolysis, the anion attacks the anode and re-forms the electrolyte. The heat of this reaction is the same as the heat absorbed in the primary electrolysis, and the secondary reaction thus exactly neutralizes the primary and V^d is suppressed, if the regeneration is perfect.

In precipitating copper from copper sulphate, using iron anodes, the reactions are

Primary $CuSO_4 = \overset{+}{Cu} - \overset{-}{SO_4}$
Secondary, at anode, $- SO_4 + Fe = FeSO_4$.

In each case, the salt is taken out of or goes into solution. We cannot analyze the different steps of this reaction, but we can take the total heats of formation of the two salts from their elements, and find their difference. For instance:

(Cu, S, O_4, aq.) = 198,400 calories = primary.
(Fe, S, O_4, aq.) = 235,600 " = secondary.

Excess evolved = 37,200 "

Therefore, voltage of decomposition

$$V^d = \frac{-37{,}200}{2 \times 23{,}040} = -0{\cdot}80 \text{ volt.}$$

In this case, therefore, the secondary reaction has furnished more energy than the primary required, and no voltage of decomposition is required, but the arrangement furnishes a voltage of 0·80 volt, and therefore acts as a battery with that electromotive force.

In precipitating zinc from zinc sulphate, using iron anodes, enclosed by a porous partition, energy is required as follows:

$$\begin{array}{lll}
(Zn, S, O_4, aq.) & = 248{,}500 \text{ calories} & = \text{primary.} \\
(Fe, S, O_4, aq.) & = 235{,}600 \quad \text{"} & = \text{secondary.} \\
\hline
\text{Deficit absorbed} & = \quad 12{,}900 \quad \text{"} &
\end{array}$$

Therefore $$V^d = \frac{12{,}900}{2 \times 23{,}040} = 0{\cdot}28 \text{ volt.}$$

Where an insoluble compound is formed upon the anode, it either protects the anode from further oxidation, or may be a non-conductor and stop the current. If copper plates are used instead of carbon anodes in the aluminium process above referred to, cupric oxide is formed, which protects the metal underneath and yet conducts the current. (Cu, O) = 37,200. While the oxide is forming, the voltage of decomposition is reduced by about

$$\frac{37{,}200}{2 \times 23{,}040} = 0{\cdot}80 \text{ volt;}$$

but as soon as the coating is continuous this advantage is lost, and the whole voltage of decomposition for alumina alone is required.

These reactions are also largely employed for manufacturing electrolytically metallic compounds from the metals themselves. By electrolyzing a bath of sodium carbonate with a lead anode, lead carbonate is formed on the anode, which continually falls off by its loose adherence and exposes fresh surfaces of lead. This serves as the basis of several attempts to manufacture white lead electrolytically.

If sodium acetate solution is similarly electrolyzed, considerable lead carbonate mixed with hydrate is formed. Metallic sulphides are made by using the metals as anodes in hyposulphite solutions, the reaction probably being that the hyposulphite radical, S_2O_3, splits up into S and SO_2, the former uniting with the metal. (Process of Roepper and Richards.) The method serves for making artificial sulphides of mercury, cadmium and antimony.

A little different is the using of copper matte, Cu_2S, as anode in a bath of copper sulphate (Marchesi process). The copper is dissolved by the SO_4 radical, while its sulphur is liberated, and drops to the bottom of the bath. The voltage developed in the union of Cu with SO_4 exactly neutralizes or counterbalances the primary decomposition into Cu and SO_4, so that the net voltage of decomposition in such a case is simply that required to decompose Cu_2S into Cu_2 and S. But $(Cu_2, S) = 20{,}270$ calories, and therefore the net voltage of decomposition is 0·44 volts.

It will be remembered, by way of contrast, that in Salom's process a metallic sulphide is decomposed as *cathode*.

B (*a*) A gas may be formed by action upon the cathode whenever the latter contains an ingredient which can form a gaseous compound with the cathion. This is the case, for instance, when metallic sulphides are used as cathodes in solutions of acids, the hydrogen cathion thus forming with the sulphur gaseous hydrogen sulphide, and incidentally reducing the sulphide to metal. The gas will at first dissolve in the electrolyte, until the latter is saturated, and thereafter escape freely, as gas. Mr. Salom, of the Institute, has protected by patent this method of reducing ores, and is at present applying it at Niagara Falls to the production of spongy lead from lead sulphide ore.

When lead sulphide is used as a cathode in a bath of dilute sulphuric acid, the hydrogen set free at the cathode, reduces the sulphide to spongy lead, forming hydrogen sulphide. The voltage required for the primary decomposition is virtually that for decomposing water, or 1·50 volts. The secondary reaction includes the two quantities.

(Pb, S)	= 18,400 calories, absorbed.		
(H_2, S, aq.)	= 7,300	"	evolved at first.
(H_2, S)	= 2,700	"	" later.
Deficit absorbed	= 11,100	"	at first.
" "	= 15,700	"	later.

When the operation begins, the hydrogen sulphide first formed dissolves in the acid, the deficit is 11,100 calories, and the secondary reactions at the cathode, therefore, *increase* the voltage of decomposition, making it greater by

$$\text{increased } V^d = \frac{11,100}{2 \times 23,040} = 0{\cdot}24 \text{ volt.}$$

After the liquor is saturated with gas, the latter escapes freely and the

$$\text{increased } V^d = \frac{15,700}{2 \times 23,040} = 0{\cdot}34 \text{ volt.}$$

The voltage absorbed in decomposition in the bath is, therefore, 1·74 volts at starting and 1·84 volts when in regular operation.

B. (*b*) When a fused zinc salt is electrolyzed with a copper cathode, the deposited metal alloys with the copper and drops melted to the bottom of the bath. The voltage of decomposition absorbed in the bath is thereby diminished by the energy of union of the copper and zinc. The most fusible alloy forms first, $CuZn_2$. and since its heat of formation is 10,143 calories (J. J. Baker), its formation diminishes V^d, as follows:

$$\text{decrease in } V^d = \frac{10,143}{4 \times 23,040} = 0{\cdot}11 \text{ volt.}$$

In the Castner process of producing caustic soda, the electrolyte in one compartment is brine, the anode being unattackable and the cathode a bath of mercury. The sodium is absorbed by the mercury with great avidity.

Decomposition of NaCl — (Na, Cl, 13 H_2O) = 97,200 and $V^d = 4{\cdot}22$

Union of Na and Hg (Hg_6, Na) = 21·600 and $V^d = 0{\cdot}89$.

Whence it appears that the voltage for decomposition in this cell is reduced nearly one volt by this secondary reaction, becoming 4·22 — 0·89 = 3·33 volts. I have observed it myself as 3·3 volts.

In the other cell of the Castner apparatus, the sodium amalgam acts as anode, the electrolyte is water, and the caustic soda formed goes into solution. The reactions in this cell are as follows:

Primary decomposition of water	= 1·50 volts.
Decomposition of amalgam	= 0·89 volt.
Formation and solution of caustic . . . . $\frac{Na_2, O, aq. = 155{,}200}{2 \times 23{,}040}$	= 3·37 volts.

There is, therefore, absorbed in the primary reaction, 1·50 volts, absorbed in one secondary reaction 0·89 volt, or a total absorbed of 2·39 volts; while the other secondary reaction, the oxidation of sodium to caustic and its solution in water, generates 3·37 volts.

$$V^d = 1{\cdot}50 + 0{\cdot}89 - 3{\cdot}37 = -0{\cdot}89 \text{ volt.}$$

We see, therefore, that nearly one volt is *generated* in this half of the cell. The first half required 3·33 for decomposition. The voltage absorbed in decomposition for the whole apparatus is therefore 3·33 — 0·98 = 2·35 volts.

B. (*c*) Examples of union of the cathion with the cathode to form a solid are not common. One is the union of hydrogen ions with platinum or palladium, to form a solid hydride. The reaction is

$$(Pt_{30}, H_2) = 33{,}900 \text{ calories,}$$

and the corresponding diminution of voltage while this reaction lasts is

$$\frac{33{,}900}{2 \times 23{,}040} = 0{\cdot}74 \text{ volt,}$$

which quantity has often complicated the measurement of the voltage necessary for decomposition of water using platinum electrodes.

When sodium ions dissolve in quantity over 2 per cent. into a mercury cathode, the Hg_6 Na formed is no longer soluble in the mercury, and separates out in the solid state. The thermal data are

$$(Hg_6, Na) = 21{,}900 \text{ calories}$$
$$(Hg_6Na, Hg_x) = 2{,}900 \quad ``$$

It appears, therefore, that when the liquid amalgam is formed, 2,900 calories less heat is given out than when the amalgam separates out as Hg_6 Na. When this happens, therefore,

$$\frac{2{,}900}{23{,}040} = 0{\cdot}13 \text{ volt}$$

less voltage of decomposition is absorbed than when the Hg_6Na dissolves in the mercury; or, perhaps, it would be more accurate to say that the secondary reaction at the cathode assists more in the former case than in the latter, by 0·13 volt.

IV.

REACTION OF THE IONS UPON THE ELECTROLYTE.

A. At the anode: Oxidizing, acidifying or perducing actions.

(1) Formation of a gas.
(2) Formation of a solid insoluble in the electrolyte.
(3) Formation of a solid soluble in the electrolyte.

B. At the cathode: Reducing actions.

(1) Formation of a gas.
(2) Formation of a solid, insoluble in the electrolyte.
(3) Formation of a solid, soluble in the electrolyte.

A. (1) The anions have generally an acidifying or oxidizing action, which may in general be termed "perducing," as opposed to the reducing action of the cathions. This influence is largely used in organic chemistry, for the purpose of oxidizing an organic compound. The chemical to be oxidized is dissolved in water, adding an acid or caustic alkali, as the case admits, then placed in a porous cell immersed in a larger jar in which is a dilute solution of acid or alkali. The oxygen set free at the anode in the atomic or nascent state acts very powerfully upon the organic compound, much more strongly than free oxygen gas would, and the current is continued until the desired degree of oxidation has been obtained. If the action is too strong or

too long continued, almost any organic compound present will be completely oxidized, literally burnt to carbonic acid gas or carbonic oxide gas and water. A good illustration of this action is when CS_2 is present in the electrolyte and oxygen is being liberated. The reaction is

$$CS_2 + 6O = CO_2 + 2SO_2$$

and a great amount of energy is thus liberated and added to the current, for CS_2 is an endothermic compound, whose decomposition *evolves* heat. We have the energy thus generated as follows:

Decomposition of CS_2 to C and S_2	= 14,100	calories.
Oxidation of C to CO_2	= 97·200	"
" " 2S to $2SO_2$	= 142,140	"
	253,740	

This is for 6O; for 1O it will be 42,290, and the reduction in voltage of decomposition which it occasions by this secondary reaction is

$$Vd = \frac{42,190}{2 \times 23,046} = 0·92 \text{ volt.}$$

In the above case a very interesting secondary reaction also occurs at the cathode, which will be considered later on.

A. (2) An example of this precipitation of an insoluble compound from solution by the action of the anion is the electrolysis of a solution of sodium hyposulphite containing dissolved silver chloride. Sulphur set free at the anode rapidly forms a black deposit of silver sulphide; which serves as one way of extracting the silver from such solutions.

If lead nitrate solution is electrolyzed with a platinum anode, a coating of lead peroxide, PbO_2, forms on the anode, caused by the oxidizing influence of the anion upon the lead nitrate solution.

A. (3) This principle of oxidizing or perducing the electrolyte at the anode is made use of largely in the chemical industries. The disinfecting of sewage is a case in point. Salt is generally present in the sewage in suffi-

cient amount (if not, it is added) and the liquid electrolyzed with aluminium or carbon electrodes. Chlorine gas is set free, in part, and hyposulphites are formed by the action of the liberated oxygen on the sodium chloride, resulting in a very satisfactory disinfecting.

The electrolysis of brine causes the formation of a considerable quantity of hyposulphite, and the liquid may then be used as a bleaching liquid. Such is the source of the "electrolytic bleach," so much used in paper mills and cotton factories.

Hypochlorites cannot exist in solution above 50°, so that, if the electrolysis of brine is conducted above that temperature, and the caustic soda formed at the cathode allowed to travel freely towards the anode, chlorate results. The action is probably that the chloride and caustic are simultaneously decomposed, giving OH and Cl ions at the anode. These unite to form HCl, liberating nascent oxygen, and the latter converts the NaCl present into $NaClO_3$. Practically all the potassium chlorate of commerce is manufactured in this way, by utilizing this secondary reaction.

The anion is often absorbed by the electrolyte, forming a higher compound. Thus, solution of cuprous chloride on being electrolyzed deposits copper at the cathode, but the chlorine set free converts the salt into cupric chloride at the anode. $CuCl + Cl = CuCl_2 = 18{,}755$ calories. The primary reaction (Cu, Cl) absorbs 32,875 calories (1·42 volts) but the secondary evolves, as above, 18,755 calories (0·82 volt) so that the net voltage of decomposition will be 0·6 volt.

This reaction may serve as the type of a whole host of similar actions which continue until part or all of the electrolyte is thus perduced. If, on the other hand, the metal separated out at the cathode is attacked by the "perduced" compound thus produced, then, when the latter mixes with the electrolyte and gets over to the cathode, there is "reduction" back again to its original state. Thus perduction of the electrolyte may be going on actively at the anode, and reduction of the same compound be going

on actively at the cathode, at the same time. The result will be a great falling off in the amount of cathion and anion finally remaining at the electrodes, the remaining amounts being far below what the current should separate out, according to Faraday's law. In fact, when some fused salts are electrolyzed, the perduction at the anode, the diffusion of the perduced salt in the electrolyte and the reduction at the cathode are so active and effective that no products of electrolysis can be found at all, under ordinary conditions, and the substance appears to conduct the current without decomposition. Such was the apparent metallic conductibility of fused lead iodide observed by Faraday, but finally explained as above by Beetz; and such is the reaction which occurs in the manufacture of metallic sodium by electrolyzing fused caustic soda. Above 325° re-combination on the above principles is so extremely active that 1,000 ampéres may be sent steadily through a small pot of melted caustic soda without any sodium being obtained; the bath lying quiet and appearing to conduct like a bath of metal; between 310° and 320° sodium is produced abundantly.

B. (*1*) When water is electrolyzed with carbon bi-sulphide present in it, the hydrogen ions, being nascent, act very strong on the CS_2 at the cathode, forming methane gas, CH_4, and hydrogen sulphide; the reaction being:

$$CS_2 + 8\ H = CH_4 + 2\ H_2S.$$

The heat equivalent of the secondary reaction is

Decomposition of the CS_2	14,400	calories.
Union of H_4 and C	21,500	"
" " H_4 and 2S	5,400	"
	41,300	"
For one atom H	= 5,160	"

$$\text{Whence, reduction of } V^{d} = \frac{5,160}{23,040} = 0{\cdot}22 \text{ volt.}$$

If we consider this reaction in connection with the secondary oxidation reaction at the anode, the voltage of decomposition is lowered by the presence of the carbon

bi-sulphide 0·22 volt at the cathode, and 0·92 volt at the anode, a total of 1·14 volts. This great reduction in voltage and the liberation of methane at the cathode may, together, account for the beneficial results obtained in gold plating by adding carbon bi-sulphide to the bath.

The remaining examples of secondary reactions at the cathode include many very important chemical processes. The cathion may act upon the solvent or upon the salt being electrolyzed; it may produce compounds soluble or insoluble in the bath. The general action being reducing, lower salts are often formed.

If, for instance, I electrolyze cuprous chloride, CuCl, the chlorine evolved at the anode may combine with the bath to form $CuCl_2$, and so rapidly that almost no chlorine visibly escapes; but the copper cathion cannot act upon CuCl in any way, because this is the compound of copper with the least amount of chlorine, and therefore the normal amount of copper will separate out. On the other hand, if I electrolyze a solution of cupric chloride, $CuCl_2$, the conditions are the reverse; the normal amount of chlorine will be set free at the anode, because $CuCl_2$ cannot be perduced to any higher chlorine compound; but at the cathode the copper will largely, if not entirely, reduce the $CuCl_2$ down to CuCl, and thus almost none remain on the cathode.

When the cathion is an easily oxidizable metal, it may react upon the water present in the electrolyte, set free hydrogen and form an oxide, which passes often into an hydrated oxide if it has power to combine with water. In the case of the metals of the alkalies, they decompose water rapidly and their hydrates formed are soluble in water. We thus obtain solutions of their hydrates, or caustic alkalies. If the metal oxidizes rapidly to an insoluble hydrate, like magnesium or aluminium, the cathode soon becomes covered with the white layer of oxide and the current is sometimes thereby interrupted.

Other reactions are the reduction of organic compounds by placing in their solutions some salt of sodium, and then electrolyzing them in a porous cell, with the cathode immersed in them. The reducing action is strong and is uil-

ized for the same purpose as ordinary reduction by sodium or by zinc dust, or other reducing agents.

B. (2) A good example of this action is the deposition of gold at the cathode when electrolyzing a solution containing potassium auro-cyanide, $K_2Au(CN)_2$. It has been proven by Hittorf that this salt decomposes as follows:

$$K_2Au(CN)_2 = \overset{+}{K} - \overset{-}{Au(CN)_2}$$

The anion splits into CN gas, which is evolved, and Au CN which goes again into solution. At the cathode the K ions react on the auro-cyanide in solution, depositing therefrom Au, as follows:

$$K + K\,Au(CN)_2 = Au + 2\,KCN$$

The precipitation of the gold is thus purely a secondary reaction. The thermal data for calculations are lacking.

Another illustration is the electrolysis of solutions of aluminium salts, such as $AlCl_3$. The aluminium ions decompose the water, forming aluminium hydrate. The reactions are:

Primary . . . . $2AlCl_3 = \overset{+}{2Al} - \overset{-}{6Cl}$
Secondary, at cathode . . . . . $2Al + 6H_2O = Al_2O_3.\,3H_2O + 3H_2.$

The thermal reactions are:

Absorbed in primary	$2\,(Al, Cl_3, aq)$	$= 475{,}560$
Decomposition of water	$3\,(H_2, O)$	$= 207{,}000$
Formation of aluminium hydrate	(Al_2, O_6, H_6)	$= 388{,}800$
Net heat evolved in secondary action		181,800

The voltages of decomposition are therefore:

Primary V^d absorbed $= \dfrac{475{,}560}{6 \times 23{,}040}$ . . . . $= 3{\cdot}44$ volts

Secondary V^d developed $= \dfrac{181{,}800}{6 \times 23{,}040}$ . . . . $= 1{\cdot}32$ "

Net V^d in the electrolysis . . . . $= 2{\cdot}12$ "

This reaction is utilized in electrolyzing impure water, after adding an aluminium salt, whereby the water is oxygenated and purified at the anode, and the aluminium hydrate precipitated at the cathode carries down impurities mechanically.

B. (*3*) The formation of alkaline hydrates is the best example of this kind of secondary reaction. In electrolyzing sodium chloride solution, using unattackable electrodes, the primary decomposition is into sodium and chlorine; the secondary reaction is the decomposition of water by the sodium. We have, therefore,

Primary decomposition (Na, Cl, aq.) . .	= 96,510 cal.	= 4·19 volts.
Decomposition of water = 69,000		
Formation of caustic . = 111,810		
Net heat of secondary reaction	= 42,810 cal.	= 1·86 volts.
Net heat of primary and secondary . . .	= 53,700 cal.	= 2·33 volts.

This reaction is the basis of several processes for producing caustic soda from brine, using a porous partition to keep the caustic produced to itself.

In conclusion, one may well say that to understand secondary reactions properly, is to have an insight into the most subtle problems of electrolysis, and puts one in position to understand the why and wherefore of all electrolytic processes. This knowledge cannot be gained except by having a thorough working knowledge of chemistry, a complete acquaintance with electrical experimenting, practice and theory, and an ability to see, to think and to search for oneself. The electro-chemical and electro-metallurgical industries are at present in need of men with the above equipment, and the progressive universities and technical schools of our land are giving increasing attention to supplying that need.

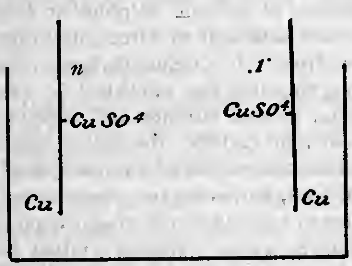
DEPARTMENT OF METALLURGY,
LEHIGH UNIVERSITY, March 4, 1901.

DISCUSSION.

MR. JESSE PAWLING, JR., asked whether it is not true that when a salt is in solution it is broken up into ions, whether a current is passing or not? This was answered by DR. RICHARDS in the affirmative and he stated that when no current was passing, the molecules were arranged in no particular order, and that a current had the effect of directing them so that one set of ions, the positive, go to

the cathode, and the other, the negative, go to the anode. At the meeting of March 21st, DR. RICHARDS, in answer to some question, stated that the metals were liberated at the kathode in a metallic form, while they were liberated at the anode, if at all, in combination, unless there is a combination of a metal with an element which has both metallic and non-metallic properties, in which case the more metallic element goes to the cathode and the less metallic to the anode. MR. PAWLING asked if this were always true and Dr. Richards answered in the affirmative, illustrating the latter part of the statement by the compounds of tellurium. In nickel telluride, the nickel goes to the cathode, while the tellurium goes to the anode. In tellurium sulphate, the tellurium goes to the cathode, while the sulph ion goes to anode as usual.

MR. REED remarked that but a small current would be



passed through a solution in which there was no mechanical agitation and emphasized the fact that mechanical agitation was necessary.

MR. PAWLING made the accompanying sketch on the blackboard, and asked whether if a current be allowed to pass if a Cu ion would not be dissolved from the anode and be combined with the SO_4 ion of 1, while Cu ion of 1 would not be combined with the SO_4 ion of 2, and so on to *n*, which in turn would give its Cu ion to the cathode. This MR. REED confirmed and also stated that mechanical agitation was necessary, because the solution in the neighborhood of the cathode would soon become dilute and but little current would pass, due to chemical action alone.

MR. CARL HERING stated that in his investigation of the action of a current in depositing lead in combination on either anode or cathode depending upon the oxide of lead forming one or the other, he used a porous partition to see upon which side the lead (or lead compound) would be deposited and hence tell which way the constituents went. He stated that the partition clogged up. MR. PAWLING asked from which side the clogging took place. MR. HERING stated that the partition simply clogged up without showing any direction of deposit.

SULPHIDE ORES

cannot, as a rule, be reduced directly by carbon, but must undergo a preliminary roasting operation to remove the sulphur, the last traces of which are eliminated with extreme difficulty, says the *Electrical World and Engineer*. Accordingly, when Mourlot directed attention some three years ago to the remarkable stability of calcium sulphide at electric furnace temperatures, the observation was sufficient to direct attention to the possibility of reducing sulphide ores directly by calcium carbide. Early in 1900 an account of investigations along this line was published by Geelmuyden, who found that pyrite, tetrahedrite, galena, stibnite and sulphide of magnesium were readily reduced by calcium carbide, the stable monosulphide of calcium remaining in the crucible, the metals of the ore being liberated and, in the cases of compounds of lead, antimony and magnesium, volatilized. Aluminium sulphide alone proved capable of resisting the powerful reducing agent.

M. Louis Michel Bullier, whose claims as original discoverer of crystalline calcium carbide have been recently upheld by the French courts, now describes an interesting extension of the foregoing principle, whereby the metals are recovered directly from mixed sulphide ores and an efficiency of nearly 90 per cent. is obtained. If copper sulphide be fused in presence of a suitable flux for which a blast furnace slag, melting, according to the patent, at about 1,500° C. is found available, and calcium carbide added in theoretical proportions, the reduction occurs readily, the calcium sulphide dissolving in the slag and the copper being recovered as an ingot free from sulphur. If copper pyrites be subjected to the same treatment it is found that the ingot obtained is composed by two sharply separated layers, of which the lower is copper and the upper iron saturated with carbon. For ores containing zinc or other metal volatile at the temperature used, a closed retort may be employed and the vapors condensed in the usual manner. The reduction of copper pyrites by this method requires an amount of 80 per cent. carbide somewhat exceeding the weight of the ore; for copper sulphide the carbide and ore are used in the ratio 1 : 2.

Mechanical and Engineering Section.

Stated Meeting, held February 14, 1901.

THE JIG HABIT IN AMERICA.

BY OBERLIN SMITH.

ABSTRACT.

The subject we have in view deals not only with those tools known as jigs, but with analogous tools of various kinds which are used for cheaply reproducing certain predetermined shapes and locations.

The grand principle of the reproduction and duplication of artistic and utilitarian forms, the originals of which were the direct embodiment of the careful thought of the artist and the engineer, is in some manifestation or other, almost as old as the world itself.

The most obvious, and perhaps the earliest, application of this principle was doubtless seen in the molding of plastic materials which could be afterwards hardened, as clay, soft metal, etc. After the world had long been accustomed to the use of molds of various kinds, the products of which could be numerously duplicated, the most notable application of the general principle which appeared was undoubtedly shown in the art of printing—from permanent engravings and afterwards from movable types. Other instances of this principle may be seen in the making of chromos and other lithographs; in the use of stencils; in the coining and stamping of metals by the use of presses and dies; and in casting metals and other substances.

A further application, differing somewhat in principle, may be seen in the use of turret-lathes and similar devices, where cutting tools are arranged for an exact repetition of their proper location, to avoid hand adjustment for each piece of work to be operated upon. A somewhat similar principle may be seen in profiling and pattern-turning machines, so called, where the movement of cutting tools

is governed by their being made to follow a master model of the work to be produced. Another instance of the same principle is seen in Jacquard looms and other weaving machines where a prearranged design, fresh from the soul of the artist, is duplicated numberless times by the use of automatic machinery, attended by cheap labor.

Still another application of the principle, and one in which we are more interested this evening, is the use of gauges, templets, cradles and jigs, these being chiefly used in the paring and cutting, to exact finished shapes, of pieces of metal which have been more roughly formed by the processes of casting or forging.

The functions of a cradle and jig are sometimes combined with those of the drilling- or boring-machines in which they are used, in the shape of a special machine which is fitted for one purpose only and which is adapted for locating the work to be operated upon, as well as the tools, in absolute predetermined positions. A good illustration of such a machine is seen in the special multiple-spindle driller which is used for boring, counter-boring, facing, reaming and tapping all the holes in a mowing machine frame, at one operation, with the assistance of cheap labor. This machine works with sufficient accuracy for the purpose, and in $\frac{1}{10}$ or $\frac{1}{20}$ of the time that would be required by ordinary methods with good machine-tools and high-priced workmen.

Speaking first of gauges, which are well enough known to make a detailed description unnecessary here, even were there time to treat of the numerous forms in which this tool appears: their general function is to inspect and verify standardized measurements. In accurate work, limit-gauges (so called) are frequently used, one representing the maximum and the other the mimimum sizes, which are allowable, the work varying between these limits at different times and to different degrees, such variations obviously representing human fallibility when attempting absolute accuracy. The purpose of a gauge is usually not so much to locate the position of various finished surfaces in a piece of work, as to inspect them and report upon them after they are so located.

Going a step farther, we have tools known as templets, which are usually flat pieces of metal (often thin sheet-metal) which are laid upon various surfaces of the work, being located by the eye or by proper flanges, pins, etc., certain edges of the templet, interior or exterior, being used to rest a scriber, or other pointed marking tool against, while marking the position of exterior edges, or of holes or grooves to be cut below its general upper surface. Such a tool will, of course, reproduce marked lines with considerable accuracy, but the drilling or cutting to these lines afterwards is subject to various errors, depending somewhat upon chance and somewhat upon the skill of the operator. If we make a templet thicker than usual and fasten it securely to the work, using the locating edges for the actual guides for cutting tools, we have the simplest form of flat jig, somewhat as shown by this pasteboard model which I have in my hand. When the exterior edges of such a jig are used to locate finished edges in the work, the tool is often known as a filing or milling jig, as the case may be. By far the most usual function of a jig, however, is to locate cylindrical holes of various sizes and kinds as made by drills and other boring tools. The simplest form of flat-jig is usually a plate of steel with certain holes accurately drilled through it at right angles to its upper and lower surfaces. If these same holes are to be drilled in a rectangular block of metal, for instance, of the shape of an ordinary brick, as represented by the wooden model I hold in my hand, then it is obvious that if the same is laid upon the horizontal table of a vertical drilling machine, with a jig clamped upon the top of it, the external edges being made to coincide by the sight or feeling of the operator, the holes in the jig may be exactly reproduced, as regards location, in the piece of work—providing the drilling tools fit the holes in the jig without shaking. Furthermore, these drilled holes may be made of any desired depth by proper adjustable stops to limit the downward motion of the drill-spindle.

In practice, such a jig as is above mentioned is often made somewhat in the form of a box-lid with downward projecting flanges or pins to slip over the work, so that it

need not be located by hand. Sometimes, clamps, screws or other fasteners are used upon one or more sides of such a jig to pull it over in one direction, so that it may be located by certain fixed edges of the work which are the most suitable. Should the work vary somewhat in size, as is the case with rough castings or forgings, it is sometimes desirable that the clamping should be central and should be done from all directions, somewhat after the manner of a universal chuck. A jig of this sort may in general be called a lid-jig and is roughly represented by the paste-board box-lid here shown.

Carrying development still further, we have the box-jig which stands upon its own bottom, so to speak, and into which the work is dropped and clamped in various directions, sometimes by the action of closing the lid—which may be hinged or otherwise secured thereto. If it is desirable to drill holes variously located and parallel to each other, in one direction only, through the piece of work in question, the jig, of course, always stands upon its bottom. It may, however, be required that other holes in other directions shall also be drilled. Thus, it is often the case that a jig, if of an approximately cubical shape outside, is turned over upon several or all of its six sides, the holes being drilled, of various depths, from any of the six directions, represented by lines normal to the various sides of a cube. Should still other directions be required, the outside of the jig can, of course, be made with various working "bottoms," upon which it can be temporarily laid. These can be at any desired angle with each other, and each is, obviously, placed opposite to the surface where the holes are provided for the drill to enter.

One of the most common illustrations of the use of jigs of this sort is found in the drilling of sewing-machine frames, where the work usually consists of an iron casting of very irregular shape. Being dropped into its jig, it is located by certain surfaces which are most favorable for producing uniformity; in some cases some or all of these surfaces being previously finished by milling, or otherwise. This jig is then slid along upon the table of a gang drilling

machine, each spindle of which carries the proper tools for drilling, boring, reaming or tapping certain holes. The downward stroke of each tool is governed by a proper stop, and thus, by cheap labor, any number of accurate holes may be located and drilled in rapid succession by a proper manipulation of the jig, it resting on any desired bottom and being pushed along from one drill-spindle to another. In such case the work is, of course, not disturbed in its position in the jig, during the complete operation in question.

In some cases a simpler form of the above-named jig can be used, the general shape of which is a flat plate with various legs projecting downward. Its general form may appropriately give the name of stool-jig to a tool of this kind. The work is placed between the legs and clamped up against the plate, not having a proper bottom of its own on which to rest, as is the case with the lid-jig.

Another modification of the box-jig may be known as a skeleton-jig, which, instead of having complete sides enclosing the work, is made in the form of a light skeleton frame. This tool is often necessary in heavier work than that above described where it is desirable to save weight as much as possible in order that the operator may be able to easily handle, unaided, the combined jig and work.

It is obviously impracticable to treat heavy castings, such as the beds of lathes or the frames of large presses, in the jigs above mentioned. In such case it is well to do the turning, milling and planing by ordinary methods, locating the finished surfaces by various gauges and templets, after which local jigs, as they may be called, are applied for accurately locating holes by some of the finished surfaces already produced. These jigs are made to suit one or more holes, as the case may be. Being small enough to handle conveniently, they may be placed in succession on various parts of the large piece of work in question.

In making large jigs a very important point is to make them light for easy handling, but yet to get the utmost stiffness possible by very careful designing, that they may not warp, bend or twist when fastened to the work, thus throwing the holes, etc., out of place. It is usually best to

use cast iron for the frames of jigs, because the working parts will maintain their position unless strain enough is brought upon them to actually crack the casting. Jigs, on the other hand, made of forgings, steel castings or brass castings are apt to bend without its being known, thus destroying their accuracy and perhaps spoiling large quantities of work before the error is discovered.

In jigs for accurate work, and where large quantities of pieces are to be made, all holes should be bushed with hardened and ground steel bushings, made to standard external diameters that they may be easily replaced when their interior surfaces are worn by drills or other boring tools which revolve therein. In jigs for making work in large quantities these bushings are usually securely fastened in place, but so that they can be knocked out when too much worn. In other cases, where the jig is used for larger work and has to perform upon but few pieces at a time, interchangeable bushings are often employed, a full set of them being kept in the tool room which can be used at random in various jigs.

Cheap jigs for a small quantity of work are sometimes made by drilling the working holes through the body of the cast iron of which they are made. These, of course, are durable only to a limited degree. In some cases, instead of bushing each hole, a hardened steel plate, with the proper working holes drilled through it, is fastened to the frame work of the jig proper. One difficulty in this system, however, consists in the fact that the warping of the steel in hardening is apt to somewhat displace the holes in their relation to each other.

The title of this lecture implies that there is a state of mind and a state of practice known as a "jig habit."

The tendency to use not only jigs themselves, but analogous tools embodying the same grand general principle for the accurate and rapid development of interchangeable parts of machines and other structures may be termed a habit of mind. Why this mental condition is prevalent in certain places and with certain people more than at other places and with other people, is a question for the psychol-

ogist. That it does exist to a greater extent in North America than in other countries in the world, and that it is found more especially in that class of Americans (no matter where they are born) whom we may term "Yankees," is, I think, an indisputable fact. These people are of a class who are born to be mechanics, and who have been brought up in an atmosphere permeated with intense practical energy.

The American who possesses this habit (usually both born and acquired) seems to have been developed during the last hundred years or so by reason of coming, in the first place, from good English and other European stock in whom common sense is a chief characteristic. The evolution of the jig habit seems to have come from these men being cast upon their own resources in a new country, where novel and original methods were often forced upon them. and where much freedom of thought and action enabled them to study for themselves methods which would allow them to carry out their mechanical ideas upon the most economical basis—not only for the love of the money to be procured thereby, but from an innate love of mechanical things put into their simplest forms.

SLAG-WOOL FOR BUILDING WORK.

The English journals have lately been calling the attention of their readers to the considerable extent to which the so-called mineral-wool, or slag-wool, is used as a non-conducting filling in floor and partition spaces in building construction in the United States. They refer to the fact that the material is excellently adapted for this purpose on account of its absolute cleanliness, that no vermin of any sort will live in it, that it is an admirable preventive of the spread of fire through hollow walls, floors and partitions, while its heat insulating quality for the purpose of keeping walls and floors at uniform temperature is no less valuable. One of the prime advantages of the material, in fact, is the last named property of warmth and in the saving of fuel resulting from its use in filling the space between the studding. One of the leading iron trade papers in England speaks of the product as an ideal material for such use in buildings, and attributes the neglect of it by English architects to the circumstance that it was first used largely for steam-pipe coverings, a use for which it is least adapted, because of its disposition to pack in certain parts of the pipes on account of the constant jarring to which most steam-pipes are subjected. Also it is intimated that considerable misapprehension exists as to its cost. Neither of these objections apply in the present case, as it is very well adapted for building uses and is comparatively inexpensive. W.

SOLDERS FOR ALUMINUM.

The one great drawback to the application of aluminum for a large number of uses in the arts for which its lightness, color, resistance to oxidation and the ease with which it can be rolled, drawn into wire, pressed and spun up into various shapes, etc., is the difficulty of soldering joints. While some approximations have been made to a durable solder, among which that of Richards' should be named, it is nevertheless true that an entirely satisfactory solution of the problem has yet to be found.

The difficulties encountered are threefold: (1) The high heat conductivity of aluminum, which abstracts heat rapidly from the joint and (2) galvanic action between the aluminum and the metals of the solder by which the aluminum, the more electro-positive metal, is corroded and the joint destroyed.

It is comparatively easy to make an apparently perfect soldered joint of aluminum with various mixtures of zinc and tin, for the reason that when freshly made, the adherence is all that could be desired. The effects of the galvanic corrosion may make themselves apparent after the work has been exposed to atmospheric influences for some months. The rapid heat conductivity of the metal can be practically obviated by applying artificial heat to the joint while the solder is being applied. It has been proposed to use aluminum in considerable proportions in the solder to avoid the effects of galvanic action, but while this artifice might accomplish the desired result, the joints cannot be made with the soldering iron, because of the high heat required to melt the alloy. A perfect solder for aluminum is still to be found. W.

CONCERNING CALCIUM CARBIDE.

In a recent article on the analysis and purification of acetylene, Rossel and Landriset quote figures which show that the proportion of hydrogen by volume in commercial acetylene usually ranges from 0·2 to 0·3 per cent., and does not exceed the latter limit even when the carbide is made in the presence of an excess of lime, says the London *Electrical Review*. Using an alternating current in the furnace, part of the lime excess volatilizes and part melts without decomposition, yielding a carbide of specially fine crystalline appearance; only the small residue is dissociated to metallic calcium, and, according to the present authors, only that part of the residue which happens to be in the middle of the finishished lumps of carbide remains as metal, and generates hydrogen when it comes in contact with water. Hydrogen in acetylene is objectionable since, burning as it does with a non-luminous flame, it reduces the illuminating power of the crude gas. It is known that a considerable quantity of hydrogen may exist in acetylene when the gas has been generated in a faulty apparatus which encourages overheating, and the quantity may easily reach a figure that seriously affects the reading of the photometer. This hydrogen is due to various decompositions occurring in the process of evolution, and it can be totally avoided by proper construction of the generating plant. The hydrogen arising from the metallic calcium of the carbide is naturally unavoidable; but Rossel and Landriset clearly show that its amount is too small to be in the least degree sensible to the consumer. Indeed, it is difficult to understand how any appreciable amount of metallic calcium can appear in a material made in an alternating furnace, where true electrolysis is theoretically excluded.

Section of Photography and Microscopy.

Stated Meeting, held Thursday, February 7, 1901.

The WAGER EXPOSURE SCALE for CORRECTLY TIMING PHOTOGRAPHIC NEGATIVES.

By E. Wager-Smith.

It is probable that you will all agree with me that, for the beginner at least, the correct exposure of his negatives is the *sine qua non* of his success, and even when he understands how to correct the exposure during development, and how to intensify and reduce his negatives after development is completed, he will save himself a great deal of useless drudgery, and will have very much better success if, at the outstart, he correctly exposes his plates.

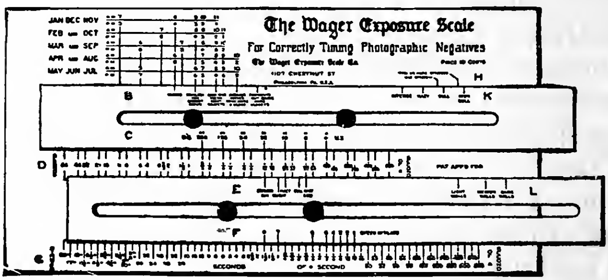
The question is, therefore, how shall he determine this correct exposure in each individual instance? and I venture to say that the inability to answer this seemingly simple question has driven thousands of amateurs from the field, and has caused the expenditure of millions of dollars in ruined material.

Some claim that through long years of experience they have learned to "feel" what the correct exposure should be, but it has been pretty clearly shown that this "feeling" is nothing more than knowledge, and does not extend much further than cap exposure, with regular known stops and plates.

The next time any one tells you that he can "feel" the correct exposure in every case, ask him how long he would expose a given subject, using, say an f/26 stop, and a plate $7\frac{1}{2}$ times as slow as the fastest made, and you will find that unless his mental arithmetic is of a high order, he will need a paper and pencil to figure it out.

I think this shows quite conclusively that he merely "feels" what he knows, and no more, and as his knowledge is only partial, his "feeling" will be only partial, and therefore inadequate to the demands which will be made upon it.

Others will tell you that the only way to be sure you are going to give your subject the correct exposure is to first refer to some similar exposure you have made, and gain knowledge from that. Aside from the obvious fact that if the beginner were to follow this advice literally, he would never reach the point where he could expose a plate, for he would never have a record to which he could refer. If you consider the size of the note book we would require for this purpose, the months and years which would elapse before it was filled, or even half filled, and lastly, the time it would take to find the record of an exposure similar to the one you were about to make, it seems to me that the scheme would hardly recommend itself to the thoughtful amateur.



You might think that the professional had solved the question of exposures, and he has—up to a certain point.

He goes just about as far as the man who feels.

Further, the range of a professional's work cannot, as a rule, compare with that of an amateur. The latter may be compelled to make two exposures within five minutes of each other, the first one requiring $\frac{1}{100}$ of a second, and the other ten seconds, or 1,000 times as long. It may even become necessary for him to make two exposures on the same day, one of which will be 500,000 times as long as the other.

Now, let us consider for a moment the factors which govern the length of an outdoor exposure.

We have, in the first place, the month of the year, the hour of the day and the condition of the weather—these

three give us the actinic value of the light. Then we have the subject, the size of the diaphragm and the speed of the plate.

There are also two other factors, which have as much bearing on the subject as those mentioned. The first may be expressed by one of the best maxims ever laid down for the guidance of beginners. It reads: "The temperature of the developer is of just as much importance as the length of the exposure." The other factor lies in the fact that the shutters now on the market do not, as a rule, give the lengths of exposure for which they are marked, the one hundredth of a second ($\frac{1}{100}$) speed, will usually be found to be between ($\frac{1}{50}$) one fiftieth and ($\frac{1}{25}$) one twenty-fifth. The best plan, of course, is to get a speed tester and ascertain just what length of exposure the various markings give.

To return to our six main factors—the strength of the sun at different seasons of the year and at different hours of the day may be readily calculated. Rules which have proved to be correct have been laid down regarding the different amounts of time necessary under different conditions of the atmosphere.

Laws governing the time necessary for varying subjects have also been formulated.

The stop or diaphragm is a simple matter of multiplication and division, and the speeds of different plates is merely a matter of testing.

These different factors were tabulated in book form some time ago, and while serving their purpose to a certain extent, did not allow one to ascertain the correct exposure as swiftly as desirable, did not allow one to check the result, without going through the whole operation a second time and, as the different factors had to be carried in the mind from one page to another, magnified the possibility of an error being made.

Exposure indicators, depending on sensitized paper for their results, have also been used to some extent, but on account of the treacherous nature of this material (for this purpose) have never been favorites with the majority.

It occurred to me that if an exposure indicator could be

devised which would eliminate the undesirable features of the two styles mentioned above, it would be a great help to every amateur in the country. I decided that the then embryotic indicator *must* embody the following good points: It must be accurate, it must be simple. It must be so arranged that the operator need do no mental arithmetic whatever. It must be so arranged that the result could be checked simultaneously, and its speed of working must be phenomenal. After a long time, I brought it to the desired point, and I think you will find that it has every one of the good qualities I determined it should have at the outstart.

You will notice that the device is composed of three pieces, two of which slide upon the third, and as the best way to show you the working of the invention will be to select a certain set of factors, and see what exposure their combination gives, we will suppose that you wish to take a photograph of a snow scene at 9 A.M. in January.

Selecting the horizontal line for January (at the top of the scale) we follow it with the eye to the point marked 9 A.M. We then move the upper slide until the line for "snow" is immediately below this point, and without further manipulation of the device, find that the exposure with a No. 16 stop is ($\frac{1}{25}$th) one twenty-fifth of a second (this being found on the central scale "D," immediately below the "stop" scale "C").

If the sun is intense and fastest plates are being used, we proceed at once to take our picture. But we will suppose that the sun merely casts a faint shadow, and that we are using a Cramer slow iso plate. We would then move the lower slide so that the word "hazy" would come right below $\frac{1}{25}$th second (already found) and upon looking below "7" in the "F" scale would see 1 second in the "G" scale. This would be the proper exposure under the six different conditions named. I should say here, that the different standard plates on the market are arranged in numbered groups on the reverse of the scale according to their speed, and that "Cramer Slow Iso" will be found in group No. 7.

I have also added the scales "H," "K" and "L," which, in conjunction with the scales "C" and "F," give the correct exposure for interiors under ordinary conditions.

I am glad to say that the words "patent applied for" are no longer correct, as my application was granted just a few days ago.

If anyone has any questions to ask, I shall be happy in answering them.

DISCUSSION.

MR. ALTENEDER:—"Will you explain how you obtained your results?"

MR. WAGER-SMITH:—"I took for my starting point, the fact that in June, at mid-day, with an intense sun overhead, one twenty-fifth ($\frac{1}{25}$) of a second will be required, when using a No. 16 stop, to correctly expose an average landscape. The sun's strength on any day may be represented by a curved line, and if ordinates be erected at the proper points, and their length compared with the ordinate for June 21st at 12 M, the proportional sun strength of the hour and day under consideration will become apparent.

Different subjects require more or less time than an average landscape, and I have proved that the constants which I employ are correct: the same may be said of the different conditions of the atmosphere, while, as I remarked before, the stop is a case of multiplication or division, and the plate is a matter of testing.

I believe this answers your question in a general way.

NOTES AND COMMENTS.

FILTH IN SAUSAGE-SKIN.

Dr. Shilling is credited with the discovery of a new mystery in the composition of that already sufficiently mysterious article of diet—the sausage. Says the London *Lancet:* "He had often remarked molds lodged in the inequalities of the inner surface of the skin. He examined pieces of dried gut such as are found in the market, and was surprised to find adhering to them a considerable amount of *débris* of straw and fragments of grain. He argued that if such remains were fairly abundant after drying, they must be still more so in the fresh guts used by pork-butchers. He had some difficulty in procuring samples, as only enough is prepared for the needs of the makers, and they are not willingly sold. After repeated examinations, he satisfied himself that these intestines of oxen or pig contained an amount of excremental matter which may be estimated at from 2 to 2½ grams per meter [10 to 12 grains to the foot] of small gut, and 5 per metre of large. If the skin of sausages is carefully removed, only a small part of this filth is swallowed; but, if they are eaten with the skin, a considerable quantity must be swallowed. Dr.

Shilling estimates that a German workman consuming 10 to 15 centimeters [4 to 6 inches] of sausage daily swallows 4 to 5 grams [62 to 77 grains] of excrement in the week, or 20 grams per month. One need only, he says, see the butcher prepare the guts by washing in a little dirty water to know in what state they must be in regard to cleanliness. He admits that it is not easy to clean the intestines thoroughly, and he is not clear as to the pathological effects that may be caused by eating the matters referred to. There can be no doubt, however, that such substances answer to the definition of dirt as 'matter in the wrong place,' and, to say the least, they can hardly be regarded as wholesome articles of food. They are certainly not appetizing. Hog's dung taken in water and wine had a great reputation in the Middle Ages as a remedy for blood-spitting and pain in the side. But the return of the *Saturnia regna* of organotherapy which appears to be in prospect has not yet led us to this particular medication. And, whatever may be its therapeutic virtues, most people would probably prefer not to have it administered in their morning sausage."

THE NATIONAL BUREAU OF STANDARDS.

The *Popular Science Monthly* says: "The bill establishing a National Bureau of Standards, which was passed by Congress in the closing hours of the session, is a measure of unusual importance for science and for industry. Such an institution has long been urgently needed. Germany expends $116,000 annually on its corresponding institutions, and it is not difficult to trace an immediate connection between its Reichsanstalt and the supremacy of German scientific instruments and the increasing manufactures and export trade of the nation. Great Britain has recently been persuaded by the British Association and the Royal Society to extend its work, and is now erecting a new physical laboratory, while it provides $62,000 annually for the cost of its different institutions engaged in standardizing and experimental tests. In the United States the sum of only $10,400 has hitherto been set aside for the Bureau of Standard Weights and Measures, which has now been converted into a National Bureau of Standards. For the Bureau a building is to be erected which may cost $250,000, though only $100,000 is at present appropriated; $25,000 is allowed for land and $10,000 for equipment. The salaries amount to over $27,000 annually, and the sum of $5,000 is given for current expenses. The bureau has been inaugurated under the most favorable auspices. Urged by scientific men and societies, on the one hand, and by engineers and manufacturers on the other, the bill passed both Houses of Congress almost without opposition. This was in large measure due to Secretary Gage and to the Hon. James H. Southard, Chairman of the Committee on Coinage, Weights and Measures, who gave the measure careful consideration and, impressed with its importance, used every effort to secure its passage. The President has already appointed a most excellent director in Professor Stratton, who has now leave of absence from the University of Chicago to take charge of the Bureau of Weights and Measures."

SMOKELESS FLASH LIGHT.

The magnesium flash light powders commonly employed for photography make, as everyone knows, a very disagreeable cloud of smoke. M. Charles

Henry has been experimenting with a view to doing away with this disagreeable feature. His results are communicated to *La Photographie* by M. L. P. Clerc, and are thus condensed in the *Revue Scientifique* :

"M. Charles Henry has endeavored to keep the magnesia that is formed as much as possible attached to a heavy substance that will not easily fly about and falls soon by its own weight—namely, the binoxid of barium. This substance, at a red heat, gives up half of its oxygen, and its salts communicate to flames a brilliancy of greenish fire, which partially corrects the undue proportion of violet and ultra-violet rays emitted by incandescent magnesia. Finally, the binoxid swells when heated and becomes capable of retaining the light powder of magnesia formed in contact with it. The sole condition to be observed, that the binoxid may be reduced with incandescence, is to remove it vigorously from all contact with oxygen. To this end, and also to insure the inflammability of the mixture, the powder is done up in collodion, whose products of combustion constitute a reducing atmosphere, adapted to the dissociation of the binoxid of barium at the lowest possible temperature ; all the elements of such a powder thus play an active part at the highest point. These powders have, besides, a great advantage over those made of patassium chlorate ; they are absolutely inexplodable by the stroke of a hammer, and are inodorous and without danger from the physiological point of view."

M. Henry, we are told, has prepared two types of powder that differ in their proportions of the binoxid ; the first, which has only a little magnesium, gives only 45 to 50 per cent. of smoke, whereas ordinary powders give 75 to 90 per cent. The other is richer in magnesium, burns more slowly, and can be used advantageously only in a special lamp, when the proportion of smoke falls as low as 10 per cent., and the brilliancy, owing to the high temperature to which the magnesia is raised, is very great.

EXTENT OF THE TEXAS OIL FIELD.

Robert T. Hill, of the United States Geological Survey, who has just returned from a thorough geological investigation of the Texas oil district, has embodied the results in a report in which he says :

The importance of this oil field is far greater than at present can be described or estimated. It means not only a cheap fuel supply to the largest State in area in the Union, but, owing to its proximity to tidewater, it promises an export trade such as exists nowhere else in the world. Preparations are being made to sink hundreds of wells, and very soon the present output of 500,000 barrels a day may be quadrupled.

It is entirely within the limit of probability that oil will be found at many places throughout the coastal prairie, especially in its southern extension toward the Rio Grande and in the Northeastern State of Mexico at Tamalipas. The outcrop of the territory formations in Southwest Texas, in Wilson, Atascosa, McMullen, Duval and other counties is naturally rich in oil, and the practical oil men are risking their money in experimenting in that region. As the oil-bearing territory extends east of the Mississippi into Mississippi and Alabama, it is not beyond possibility that oil may be found in these States.

It is impossible now to state exactly the extent of the oil-yielding bed

which supplies the Beaumont well, and this can only be determined by drilling experiments.

The area of profitable exploitation of the Beaumont oil fields is confined between the San Jacinto and the Sabine rivers, east of the Houston & West Texas Railroad and south of Oil City, Nacogdoches County. This area may be extended or restricted by future exploitation.

It is very probable that other oil fields may be discovered in the coastal plain between Beaumont and Tampico fields. Here lies a vast territory, underlaid by the oil-bearing eocene formations which has not been exploited. W.

THE DETERIORATION OF PAPER.

A committee of the London Society of Arts which has had under investigation the causes of the deterioration of paper, announces the following conclusions:

The report makes special reference to the revolutionary changes in the paper industry that have taken place during the past century. They relate not only to the enormous growth of the industry, but specially to the introduction of new fabrics and materials which have taken their place as indispensable staples. Pulp made from wood is the most important of these new materials, and while it is admitted that it constitutes in many respects an efficient substitute, the conclusion is reached that many of these wood pulps are distinctly inferior in respect of the durability of the paper made from them than that made from the celluloses obtained from the old-fashioned materials, cotton, flax and hemp which were the exclusive staple materials for paper-making prior to the introduction of wood for the purpose.

The committee examined many specimens of deteriorated paper in books submitted to its members by librarians and others, some of which were in a state of complete disintegration, and made many independent examinations.

The report finds that papers exhibit a tendency to deteriorate in two days (1) by disintegration, and (2) by discoloration. These effects may occur independently or concurrently. Disintegration is notably exhibited in papers containing mechanical wood-pulp, although it was shown to occur in papers of all grades, from the best rag papers to the cheapest wood papers, though by no means to so great a degree in the former.

The disintegration was shown to be caused by the chemical changes taking place in the films themselves. In the case of rag papers the disintegration seemed to be due to acid bodies, while in the case of the wood pulp papers it was found to be due to oxidation, the effect being accomplished by a basic or alkaline reaction of the paper.

Papers of all grades were found to be susceptible to the second defect of discoloration, and without entering minutely into the chemistry of the changes, it suffices to state that this effect is traceable to the sizing operation to which all paper is subjected. It was the committee's purpose to give to its labors a practical value by the suggestion of standards of quality. With this object, the report presents the following specific suggestions for a normal standard of quality for book papers required for publications of permanent value, viz: Fibres: not less than 70 per cent. of fibres of the cotton flax or hemp class. Sizing: Not more than 2 per cent. rosin and finished with the normal acidity of pure alum. Loading: Not more than 10 per cent. mineral matter (ash). W.

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Mining and Metallurgical Section.

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REMARKS ON THE EARTHQUAKE IN THE STATE OF COLIMA, MEXICO, JANUARY 19, 1900.

BY CASPAR WISTAR HAINES,
Member of the Institute.

On the night of the 19th of January, 1900, at 11.50 P.M., local time, a very severe earthquake was felt in Mexico over a comparatively narrow zone, extending, approximately, along the nineteenth parallel of latitude and reaching from the Pacific Ocean to the Gulf of Mexico.

It greatest force and longest duration were felt at Colima, on the Pacific Coast, where it lasted seventy five seconds. The duration and intensity diminished towards Veracruz, on the coast of the Gulf of Mexico, where it was scarcely perceptible, and where it seemed to disappear into the waters of the Gulf, as it had appeared from those of the Pacific Ocean.

The territory affected by the disturbance may be said to have been enclosed within the eastern half of an ellipse—or of a figure roughly approximating an ellipse—whose centre was at a point in the Pacific Ocean not far west of Manzanillo, latitude 19° 3′ north, longitude 104° 30′ west of Greenwich.

It is interesting to note that "it was in Manzanillo that were built, in 1564, the vessels composing the expeditionary squadron, which, under command of the gallant Don Miguel López de Legaspi, conquered the Philippine Islands."

This ellipse passed through, or close to, Rosario, Sinaloa, Aguascalientes, Dolores Hidalgo, Zacapoaxtla, Veracruz, south of Alvarado, Acatlán, Chilpancingo, Zihuatanejo. The line passing through these places may be considered as the extreme limit of movement, for at them it was not perceived by many persons, and beyond them nothing was felt.

The district most strongly affected was bounded by a concentric ellipse passing through, or close to, Cabo Corrientes, Autlán, Zapotlán (Ciudad Guzmán), Rio del Oro, Coalcomán, Boca de Apiza. In the district between the two bounding lines the intensity varied greatly according to the situation, and also, apparently, to local geological conditions. Friends at Puebla told me that they scarcely felt any motion.

Within the whole territory bounded by the outer limiting line there is only one distinctively active volcano, that of Colima. Indeed, there are only two in the whole of Mexico, Colima and Jorullo, in the State of Michoacán, about 300 kiloms. southeast of Colima.

Situated along the axial line of these ellipses, and grouped near its eastern end, are the principal extinct volcanoes of Mexico: Nevado de Toluca, Popocatepetl, Cofre de Perote and Citlaltepec, more commonly known as the Peak of Orizaba, which has now been determined to be the highest mountain in Mexico.

Popocatepetl has generally been considered extinct for centuries, and I have never seen smoke from it, although I have lived within sight of it for years; but I have been told

by friends who ascended it, that the fumes of sulphur are very strong on the leeward side of the crater, and that there is fire in crevices and holes far down in its depths.

In prehistoric times, which were probably not very remote, geologically speaking, Perote must have been a volcano of prodigious activity. There is a well-defined lava-flow extending from the mountain to the Gulf of Mexico, a distance of 80 kiloms. It is several hundred metres wide, but the width varies greatly at different places.

Mr. A. M. Wellington speaks as follows of these volcanoes in his paper on "The American Railway Line from Veracruz to the City of Mexico:"

"Orizaba is one of the three mountains in Mexico covered with perpetual snow, the other two being Popocatepetl (17,884 feet), and Ixtaccihuatl (15,705 feet) overlooking the valley. These, however, start from a plain 8,000 feet high, whereas, Orizaba starts practically from sea-level on the coast side, making it in that sense by much the highest mountain on the North American Continent, and among the highest in the world.

"(Mt. St. Elias, in Alaska, is a possible exception, being only about thirty miles inland, and its height variously given as 14,970 feet, 16,900, 17,850, over 18,000 [U. S. Census Report] and 19,500.)

"Its snow-clad peak is visible sixty miles at sea, long before there is any other evidence of land, and with the morning sun shining on it is a very striking sight. Its last eruption was in 1546, soon after the Spanish conquest, although it now occasionally throws out smoke. Only one or two men have ever ascended to its crater, the first having been Lieutenant Reynolds, U. S. A., in 1848. The line of the Mexican Railway passes to the south of the mountain.

"The 'Cofre,' or 'Box,' of Perote (so named from a cylindrical basaltic needle about 360 feet in diameter and 300 feet high which caps the mountain, like a box laid on its peak), although formerly one of the most active volcanoes in the world, and classed as still active, is perhaps permanently extinct, its last, and probably also its greatest,

eruption having been to form what looks to be, and is in fact, a frozen river of lava, extending to and running into the sea fifty miles distant, filling up an enormous barranca or deep gulch in the process, in a manner which was very convenient for subsequently carrying the line over it. The natural variations in the width of the gulch have caused lakes and frozen 'water-falls' of lava, which makes it difficult to believe, as one looks upon it from some commanding point, that the mass is not still flowing, making a unique and impressive bit of natural scenery. Vessels have frequently been wrecked on the toe of this flow where it enters the sea. It has still hardly any deposit of sand, soil, or vegetation on it, that and other facts evidencing that the flow is geologically very recent, not antedating much the historic era."

Perote is a spur of, and joined by a narrow ridge to its gigantic neighbor Citlaltepec, whose Aztec name "Star-hill" (from Citlatl, a Star and Tepetl, a hill) does not come from any sign of volcanic fire seen at the summit, but from the beautiful effect of the sun shining on the white, eternal snow of its almost perfect conelike peak, in the early morning or late evening, while the base of the mountain and all the rest of the country is shrouded in darkness.

The volcano of Colima was formerly active, but some time during the early part of the nineteenth century it became inactive and remained so till some time in the early '60's, since which time it has been constantly active. The eruptions consist principally of steam, or white smoke, great volumes of which puff out at short intervals, and take beautiful and capricious forms. When I was in Colima about twenty years ago, the puffs of vapor came at intervals of about twenty to forty minutes and were much larger than at present. Frequently, they would gradually roll up out of the crater, which is in the very apex of the almost perfect cone, and, expanding as they rose, form an inverted cone as large as, or even larger than, the mountain itself. At other times a straight column would rise thousands of feet above the crater and then its top would spread out like a gigantic umbrella, or mushroom.

Then again the vapors would take no definite shape, but roll out and pile up like an enormous mass of cumulus clouds, such as are often seen on summer afternoons. Frequently eruptions occurred about sunrise or sunset, and the effect of the rosy light of the "horizontal sun" shining on the mass of white vapor was indescribably beautiful and never to be forgotten. Especially was this so when seen through the graceful and rustling fronds of a grove of palm trees while the full moon was rising over the opposite horizon.

Of late years the amount of vapor seems to be less and it issues almost constantly without taking such fantastic shapes as formerly.

There are also frequent eruptions of red hot scoria, or sand, which at night show as streams of fire flowing down the mountain side for hundreds of metres. In the daytime they appear as trails of white smoke rolling down the slope. These streams of scoria do not run down the mountain side at random, but have clearly defined paths which can be seen from the city, 40 kiloms. away, and which look like troughs or gutters. They have many branches and gradually grow smaller as they descend. In time the accumulation of ashes at the crater becomes so high and unstable that it falls and covers the channel, or it is destroyed by a slide farther down the mountain. Then a new course is soon formed which in turn is destroyed.

During the period of inactivity of the volcano frequent earthquakes were felt in Colima. They reached their greatest intensity about 1847 or 1848 when there was much destruction of property. I was told by a gentleman who was 11 years old when that earthquake occurred, and remembered it perfectly, that the inhabitants were so much frightened that for many weeks they slept in booths or "shacks" set up in the courtyards of their houses, being afraid that the roofs might fall on them if they slept indoors. The same gentleman told me that the earthquake of that year was not so severe, according to his recollection, as the present one. There was also a very serious earthquake earlier in the century, about 1808, and from all

accounts it must have been fully as severe as this and perhaps even more serious.

After the volcano became active the intensity of the shocks diminished and they became less frequent, although several were felt every year. I felt several slight tremors in 1880 and 1881 but they wrought no destruction. During the last four or five years they have increased in force and have caused more damage. That of 25th or 27th January, 1899, which was quite strong in Mexico City and Puebla, was also felt with force in Colima.

It will be noticed that in two consecutive years the shocks occurred about the same day in January, and the people of Colima consider that January and February are earthquake months. At some time during those months they always expect a severe earthquake, after which—if they have suffered no harm—they feel comparatively easy for another year, for two seldom occur in the same season.

January is about the middle of the dry season, which begins in October and lasts until May or June. Severe shocks rarely occur during the rainy season—at least in Colima.

The summit of the volcano of Colima is about 3,960 metres above sea level, and about 75 kiloms. in a straight line from the Pacific Coast. It is about 40 kiloms. to the north of the city of Colima. The city is about 500 metres (at the Plaza) above sea level, and the rather steeply sloping plain on which it is situated is diversified by many water-courses and low rolling hills. It is separated from the foot of the mountain by a deep valley and a range of low hills.

The mountain is a double peak, that to the north being the higher and covered with forest to the top. As it is frequently covered with snow in winter it is called "El Volcan de Nieve." The southern peak, which is quite a regular cone, is "El Volcan de Fuego," the Fire Mountain. The two are joined some distance below their summits by a narrow ridge or "hog-back."

The crater of the volcano is at the very apex, and for several hundred metres down the sides are covered with loose scoria and sand, over which it is impossible to walk. The inclination is also very steep.

In geological times the two must have been very active, or else have formed one immense volcano, for the country far below the city is covered with loose, vitrified stones, which vary in size from pebbles to rocks of many cubic metres. All of these are apparently of volcanic origin and not water-worn; moreover, they undoubtedly seem to have been thrown to where they are found by the force of eruptions and not to have been carried by water, for they are as frequently found on the tops of hills at long distances from any sign of water action, as in the valleys and along watercourses.

Near the foot of the mountain, and not far from Zapotlán, an extensive stretch of country is covered by an ancient lava-flow. But, as scattered through it are many cupshaped depressions which look like old craters, this flow seems to have been local in origin and not to have come from the volcano, from which it is separated by a deep ravine.

Owing to intervening buildings I could not see the volcano from the house in which I lived, so could not make any personal observations on the character of the eruptions. But, as far as I could learn from friends, there had been no noticeable change in them for several days before the earthquake, nor were the shocks accompanied with any diminution or increase in their volume and frequency.

At the Roman Catholic Seminary in the city of Colima, careful observations are taken several times daily, and these show that there was little or no change in the eruptions either before or after the earthquake. Other observations taken at the same observatory show no meteorological disturbance accompanying the phenomenon.

The barometric means (reduced to O) were as follows:

Mean for the month	718 mm. 90
11th January, daily mean	717 mm. 77
18th " " "	717 mm. 56
19th " " "	717 mm. 76
24th " " "	717 mm. 12

This last was the lowest daily mean for the month.

The temperature was rather high for the time of year, being 29°9 C. during the day, and 15°8 at 9 P.M.

A night or two before the sky had been thickly covered with small, floculent clouds which are supposed to look like sheep, whence the Spanish name "cielo aborregado." This appearance of the sky is somewhat like that known here as "Mackerel Sky," but the clouds are rather more fleecy. The "cielo aborregado" is said to be a sure sign of a coming earthquake. Of the other supposed precursory signs, as a certain indescribable haziness of the atmosphere, similar to that of "Indian summer," and also an oppressive calmness and hush over everything, I noticed nothing, and although at the time of the shocks there was no wind, it was a perfectly natural calm.

The plan of the streets of Colima is, practically, rectangular and, while they are by no means perfectly straight, their general direction is north to south and east to west. The mountain is nearly north from the Plaza. Nearly all the houses are of one story, most of them built of adobe and roofed with heavy horseshoe tiles of baked clay. The façades are generally crowned with a heavy, projecting cornice of bricks and mortar. Some of the houses are constructed of wickerwork woven on posts imbedded in the ground. This is plastered with clay and whitewashed, thus making a very presentable and cheap house which is nearly earthquake-proof. Around the Plaza and scattered through the town, there are a few two-story houses, built of brick. The roofs of the more pretentious houses, and of some others built of masonry, are often vaulted or domed; the domes being made of hollow, baked-clay cylinders — or, more properly, frustrums of cones—with the ends closed and the whole plastered over.

The Colima River flows from north to south through what would be approximately the geographical centre of the town but rather to the west of the principal business portion and of the Plaza. It is a small stream, carrying, in the dry season, 500 or perhaps 1,000 litres per second. East of the Plaza are two or three small runs, also flowing from north to south, and practically without water in the dry season. The northern part of the town is much higher than the southern; but as far as could be seen, in the

absence of cellars or excavations, there appeared to be no important difference in the subsoil.

The evening of the earthquake, as I walked through the Plaza, about 11 o'clock, I was particularly impressed by the beauty and tranquillity of the night and by the brilliancy of the moonlight. I was asleep shortly after quarter-past eleven, for the last thing I can remember, just as I was losing consciousness, was the town clock striking the quarter hour.

Suddenly I awoke possessed by a nameless dread. The room seemed filled with a low, indistinct rumble, a scarcely audible pulsation, which came from beneath, from above, from all around. As it grew it sounded like the noise of a heavy wagon moving over a frozen road some distance away. Almost before I was awake I realized that it was an earthquake. As yet I had not noticed any movement of the earth although I slept on a light canvas cot sensitive to any motion. At other times I had never run out of the house during an earthquake, but this time, almost before I knew what I was doing, I had rushed out of the room, fortunately on the ground-floor, to the "Pila" (fountain) in the center of the "Patio" (courtyard) of the house. Almost at the same time our two "mozos" (servants) who slept in the hallway of the great house-door, reached the pila. Although both were natives of Colima and consequently more or less accustomed to earthquakes, their faces, plainly visible in the bright moonlight, were pictures of abject terror. The first severe shock had scarcely begun when we reached the pila, but by the time my companion could get out of his room, only a moment or two after us, the motion was very strong and it was really quite ludicrous to see his frantic efforts to run. His actions were very much like those we all make when trying in the dark to reach that delusive top step which we always find is not where we expected it to be.

At first the motion appeared to be a slight, slow oscillation from west to east, rapidly becoming faster and more violent until a climax was reached, when it suddenly died away only to be repeated three, four or five times—I could

not count. After the first motion, from west to east, it changed to north and south, and then to trepidation. When I reached the pila I was facing south and, with my feet spread well apart, fearful lest the ground should open under me, was able to withstand the first shock; when, however, the motion changed to north and south I was nearly thrown head first into the pila and had to steady myself by putting my hand on the man who was standing beside me, facing west.

The pila is a round, stone basin about 1 m. 75 in diameter and 0 m. 75 high, all above ground, with a stone pillar in the centre for the pipe of the jet. Although full of water at the time it was nearly emptied by the motion, the water being thrown out on the east and west sides. The same thing happened to the fountains in the Plaza. I imagined that I could see the ground move in small, rippling waves which ran across the pavement of the patio, but concluded it must have been an optical delusion caused by my excitement until, the next day, a friend told me that he also had distinctly seen waves run across the pavement of the plaza, where he was at the time.

The following description, from a letter written the next day, while the impressions were fresh in my mind, will give a more vivid picture, perhaps, than anything written later:

"First there came a gentle heaving and little, rippling waves, with not much sound, but increasing and augmenting until the whole earth seemed to be rocking and swaying in waves that proceeded from west to east, while at the same time it seemed to fly up at me. This died away somewhat, and then increased to more than at first, again dying away and increasing with redoubled fury three or four times.

"The whole while there was the accompaniment of the most infernal din under ground—a sort of rrr-RRR-*RRR*—mixed with the shrieks of the neighbors, who were pouring out of their houses into the streets, the crash of falling cornices, the clang of church bells set in motion by the swaying of the towers, the howling of dogs, the stamping and screaming of frightened horses and other domestic

animals. To these may be added the groaning of the earth, and the grinding of the stones and bricks in the walls of the houses.

"The movement gradually died away with a few shivers and slight tremors, but the hanging lamps and flower-baskets kept on swinging for a long time. The nearest thing to which I can liken the quake is to the shaking of a large rug by two or four persons. They take it by the corners and give a few preliminary shakes to see if they have strong hold of the edge; then they shake vigorously and with increasing violence; stop a moment to take breath and shake again three or four times.

"According to the records at the Observatory it lasted only seventy-five seconds; but that is a long time for an earthquake. After we felt assured that it was over we examined the house and belongings. We found no cracks in the walls (which were of masonry and not adobe) that were worthy of consideration, and only one vinegar bottle and one goblet were broken. Several bottles and small articles were moved somewhat out of place and the water had slopped out of the washbasins.

"Finally, after dressing, I started out to see what had happened to the rest of the town, the moonlight being almost as bright as day. The streets were alive with frightened people. I walked to the Plaza. In the street by the cathedral was a lot of bricks, stone and mortar which had fallen from the towers, and we could see that one of the great iron crosses surmounting one of the towers was gone; but it was not light enough to see how badly the edifice was cracked. The low clock-tower on the roof of the Palace was badly cracked and the hands of the clock had fallen into the street. The stone—brick and mortar—balustrade on one of the houses on the south side of the plaza was destroyed and had fallen into the street. (Similar balustrades on houses on the north and west sides of the plaza—there were none on the east—were not injured.)

"I found a friend, who lives in a house on the plaza, standing with his family in front of his door. I went through the house with them. Several glass things had

been broken and nearly all the large earthenware flower-pots in the patio were overturned and broken. In the parlor a large glass-covered portrait had fallen on a 'what-not' which it smashed, but the picture we found on the ground leaning with its face against the piano, the glass unbroken.

"The 'O's,' who live in a gieat, rambling, one-story house with a tile roof, a couple of blocks from the Plaza, were all in the street receiving the congratulations of their neighbors because they had no damage but a fallen cornice to lament.

"The new two-story house a block above the office, into which a friend had just moved with his bride, was a complete wreck.

"I wandered about a little more, finding every house open and the people preparing to spend the night in the streets, some for fear of another shock, and others because their houses were not safe. In the morning we could see much more of the damage. The great dome of the cathedral was cracked in a dozen places, the two bell towers that flank the façade were very much shattered, and the whole building was cracked, both front and back, from cornice to foundation."

This church was destroyed by the earthquake of 1847, and had only been rebuilt and reconsecrated some ten or fifteen years ago.

"On every side through the streets lay bricks, adobes, mortar and tiles, and many houses showed cracked walls.

"The seminario is in a horrible state. There is not a wall in the building that is not badly cracked. All the houses of the poorer sort are one-story with tile roofs and no ceilings, and, as I walked along the streets, I could see through the open doors and windows that there was scarcely a roof from which the tiles had not been shaken, so that one could see the sky through the roof. Many have collapsed completely."

Early next morning the Governor appointed a commission (one member of which was a Mexican engineer, a graduate of Lehigh University, on a business visit to Colima) to examine and report on the condition of the public build-

ings. They recommended the closing of the six churches of the city until repairs which they indicated should have been made. They also practically condemned the cathedral, and within a few days workmen began to erect the scaffolding to take down the towers and to support the dome till further arrangements could be made. Of the schools they reported: Three in complete ruin, two dangerous, ten badly damaged but not dangerous nor difficult to repair, and four unharmed. The palace, although it adjoins the cathedral, was unharmed. The jail, prison and police barracks were slightly cracked, the hospital more so, and the theatre not much. The eight large gateways to the square called the "Jardin Nuñez" were badly shattered, but none fell. The arches seemed to have been sliced off the pillars at the springing line, and the tops of the pillars forced outward a couple of inches.

In Mexican architecture the top of doorway and window openings is generally an arch, either flat or circular. Where the building was racked these arches were broken at about the haunches, or thirds, and the central portion slipping down acted as a wedge to force the wall open and also to prevent it from coming together again when the motion of the earth ceased.

The main arches forming the ribs of the vault of the cathedral roof were cracked in the same way, and when I went up the next morning at first I was afraid to walk across the roof.

Most damage was done in the part of the city lying north of the plaza. In the lower ground on the south of the plaza fewer houses were injured.

Up to noon of the 20th, seven persons killed and seventy-seven wounded had been officially registered in the police reports; but there were also many wounded who remained in their own houses and were attended by their own doctors, of whom no report was made to the authorities.

Shortly after midnight there was another slight shock, but it was not perceived by many persons and, as the seismograph was in the wrecked seminario, there was no official record of it.

For many nights--nearly a month—a great part of the population moved beds out into the streets and slept there. Notwithstanding that our house was intact and the roof in good condition, I confess to feeling an uneasiness and dread when bedtime came. However it wore off in time and things returned to their normal condition in two or three weeks.

In the country outside of the city the condition of things was very bad also. On many of the haciendas the buildings were wrecked and the dry stone fences enclosing the fields were thrown down. The damage from this cause alone amounted to thousands of dollars.

A gentleman who was at his hacienda that night told me that the bellowing of the cattle in the fields and the noise of the wild animals in the nearby mountains was perfectly awful and appalling.

I did not hear of the ground cracking open anywhere near the city; but toward the ccast it opened in several places. It was said that, from some of them there was an outflow of sand. I saw nothing of the kind however.

The railroad suffered very little. At several places the sides of rock cuts were badly shattered and some loose rocks fell on the track. They continued to fall occas onally for some time (weeks) afterwards. It was, however, impossible to tell which of the cracks were new and caused by the earthquake and which were old ones from blasting during construction and had not been noticed until our attention was especially called to them. The rock was mostly very hard, vitreous limestone.

On two or three stretches, where the road had been built across the laguna and marshy ground on trestles which were afterwards filled in, the banks, although eight or ten years old, settled somewhat, and had to be filled in and resurfaced. Otherwise the track was not disturbed. The large steel through bridge carried across the Armeria River on high masonry piers showed no sign of injury. The two massive stone arch street bridges in the city—one of them very old—were uninjured, although I have felt them tremble from the force of the rushing water during a flood.

Not far from the city, in a field which has been under cultivation for generations, a hole was discovered after the earthquake and upon investigation it was found to be a short shaft at the foot of which were several subterranean chambers containing human bones and other relics which showed that the place had been a tomb of the aborigines—probably of the Aztecs—who passed through Colima during their eight centuries of wandering from "Aztlán," the place of their origin, to Tenochtitlán, their final resting place in the valley of Mexico.

The record of the seismograph shows that the greatest amplitude of oscillation was in an east and west direction. With few exceptions, all the cornices which fell were those of houses on the west side of the streets. To me this seems to indicate that the first shock, before the whole fabric began to sway in unison, came from the west and that the wall was sufficiently elastic to allow its base and lower portion to move to the east under this first impulse, while the heavy and rather unbalanced cornice retained its position in space (through inertia) until, losing the vertical support of the wall, it toppled over. The two or three exceptions were houses on the southside of the streets.

The large "regulator" clock, with compensating mercurial pendulum, which hung in the office, on the north side of a heavy masonry wall running east and west, did not stop. But, when I looked at it just after the shocks had ceased, the pendulum seemed to have greater amplitude of swing than usual. When compared with Mexico by telegraph the next day we found it had gained one or two minutes. A smaller pendulum clock hanging on the west side of a north and south wall had stopped at the hour of the earthquake. In other houses clocks hanging in the same relative positions were similarly affected.

While the motion was not perceptible to the unaided senses outside of the bounds already mentioned, it was accidentally noticed by an observer far beyond them, as is shown by a letter to *Science* (9th February, 1900) from Mr. R. H. Tucker, of Lick Observatory, Mount Hamilton, Cal., who noticed oscillations in the mercury, evidently produced by

this earthquake, upon setting the telescope for the nadir observation.

It is almost, if not absolutely impossible, for a person who has never felt an earthquake, to appreciate to the fullest extent its supreme awfulness. At first there is a momentary feeling of wonder and bewilderment, and then, when the mind fully realizes what is happening, that the solid earth is moving under one's feet—that the earth, which all our lives we have been taught to consider the very symbol of stability and immobility, is shaking and heaving like a troubled sea, terror and dread overpower all other emotions.

Happily, I never have had to face the elements in their more common manifestations of destructive force—fire, flood and wind; but it seems to me that in any of them a man has a "fighting chance," while in an earthquake there is absolutely nothing to do. One knows not which way to turn, whither to flee for safety, and in consequence feels utterly helpless.

It is terrible to think of what would happen in cities like New York, Philadelphia, Chicago and others in which there are so many "sky-scrapers." Braced as they are, within themselves and by neighboring buildings, it is not probable that the steel frames of these buildings would collapse; but it is not improbable that the outer shell would disintegrate, and the loss of life from falling brick and tiles, as well as from the ensuing panic, would be horrible.

PHYSICAL SECTION

Stated Meeting, held December 26, 1900

RECENT ADVANCES IN THE PHYSICS OF WATER.

GEORGE FLOWERS STRADLING, PH.D.
Member of the Institute.

For a long time it has been known that water, the most common of all liquids, has physical properties which vary widely from those of most other liquids. The large quantity of heat required to melt a gram of ice, the still larger quantity required to convert a gram of water into vapor at the same temperature and the existence of a temperature of maximum density between the melting and the freezing points, mark water as departing from the usual rules of liquid comportment. Already the list of the anomalies presented by water is long and yet it is no uncommon occurrence to have it increased. For instance Hauser in the July number of *Drude's Annalen* for 1901 shows that at 32° C., the viscosity of water is not changed by a pressure of 400 atmospheres, while at other temperatures it is changed.

Within the last decade serious attempts have been made to furnish an explanation of the irregularities of water. The idea that water molecules are not H_2O simply but are aggregates of this group is advanced by Raoult * as a result of his experiments upon the molecular lowering of the freezing point of solutions, and probably expressions of this view could be found long before. When in 1891 Roentgen attacked the problem he used this suggestion and succeeded in furnishing a qualitative explanation.†

He regards water as composed of molecules of two kinds, which he designates ice molecules and molecules of the second kind. Ordinary water is considered to be a

* Raoult, *Ann. chim et phys.*, Series 6, Vol. II, p. 66, 1884.

† Roentgen, *Wied. Ann.*, XLV, p. 91. "Ueber die Constitution des flüssigen Wassers."

saturated solution of ice molecules in a mass of molecules of the second kind. By the addition of heat ice molecules are converted into those of the second kind. This is accompanied by a diminution of volume, just as when ice melts.

The maximum density of water.—At 4° C. water is at its maximum density. The addition of heat to a mixture of the two kinds of molecules will cause

(1) A diminution of volume due to the change of ice molecules into molecules of the second kind.

(2) An increase of volume due to the expansion of the mass of molecules of the second kind.

The observed change in the volume of water is the difference of these two effects. When heat is applied to water at 0° a relatively large number of ice molecules are changed into the other kind and the diminution of volume amounts to more than the increase. As the temperature rises the number of ice molecules diminishes, hence fewer are changed into the second kind, and the difference be tween the diminution and increase grows less. At 4° the two effects just balance each other, while above this temperature the increase of volume is the greater.

Roentgen gives this explanation but does not claim to be the originator of it. Indeed H. M. Vernon * in the same year gave practically the same explanation.

Pressure—Volume—Temperature Relations of Water.—As the temperature of simple liquids rises, their compressibility increases, but the compressibility of water grows less with rising temperature and, according to the results of S. Pagliani and G. Vicentini,† reaches a minimum value at 63° C.

To explain this Roentgen further assumes that an increase of pressure upon a mass of water kept at constant temperature results in the change of some of the ice molecules into molecules of the second kind, and that the num-

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*H. M. Vernon, *Phil. Mag.*, Series 5, Vol. XXXI, p. 387, 1891. "On the Maximum Density of Water."

† S. Pagliani und G. Vicentini. *Beiblätter*, VIII, p. 794. "Ueber die Compressibilität der Flüssigkeiten und insbesondere des Wassers."

ber so changing is greater as the total number of ice molecules present is greater. This transformation causes a diminution of volume which is greater for a given increase of pressure at low temperatures, because then the water is richer in ice molecules. When, therefore, pressure is exerted upon a mass of water, the resulting change of volume is the sum of

(1) A decrease of volume due to the transforming of ice molecules into those of the second kind, and

(2) A decrease due to the compression of the mass of molecules of the second kind.

The first of these decreases will grow smaller as the temperature rises, because with rising temperature the number of ice molecules becomes smaller. On the other hand the second will probably become greater as the temperature goes up. At least simple liquids act thus. From the opposite effects produced upon the two decrements by a rise of temperature it is seen that their sum, which is the actually observed compressibility of water, might at some temperature have a minimum value.

The effect of pressure upon the coefficient of thermal expansion of ether, carbon disulphide and alcohol is to lower it; but for water it has been found that the mean coefficient up to 50° at least is increased, even when the pressures amount to 2500–3000 atmospheres. To find an explanation for this anomalous effect, consider how an increase of pressure will act on both of the volume changes mentioned under the heading "The maximum density of water." The first, the diminution of volume, will be made less by an increase of pressure, because thereby the ice molecules are converted into the other kind, so that there remains fewer of them to be changed by heat. Roentgen had no data by which to determine how pressure would affect the second, the increase of the volume of the mass of molecules of the second kind. He suggests that perhaps there would be but little effect upon the coefficient of expansion. Let us now compare the thermal expansion of a mass of water under a pressure of one atmosphere with the expansion under a higher pressure, the rise of temperature

being, for example, from 5° to 10° C. in both cases. The observed expansion under both pressures is the expansion of the aggregate of molecules of the second kind minus the decrease in volume due to the change by heat of some ice molecules into the others. Under the higher pressure the minuend is larger because there are more molecules of the second kind in the water, and the subtrahend is less because the number of ice molecules is smaller. The remainder, the observed thermal expansion, is therefore larger for the higher than for the lower pressure.

Amagat finds that at high pressures water comports itself as an ordinary liquid. This finds its explanation in the disappearance of ice molecules. His results likewise show that the effect of pressure upon the coefficient of thermal expansion is most marked when the temperature and the pressure are low. This is understood when it is recalled that the number of ice molecules is greater at low pressure and at low temperature.

Lowering of the temperature of maximum density by pressure.—The temperature of maximum density moves downward from 4° C. as the pressure upon the water is made greater.

According to the view already advanced, at 4° C. and under atmospheric pressure the effect upon the volume of a mass of water caused by a small increase of temperature is zero, because there the two opposite volume changes just balance each other. An increase of pressure lessens the number of ice molecules and consequently gives to the expansion of the mass of molecules of the second kind the preponderance. Under this increased pressure, then, the balancing of the two effects no longer occurs at 4°, but at some lower temperature, where the water is richer in ice molecules.

By pressure water can be cooled below 0°C. without freezing, because the pressure prevents the formation of ice molecules.

Viscosity of water.—Water under pressures of several hundred atmospheres is less viscous than at normal pressure, provided the temperature does not exceed 32°C. Other liquids which have been investigated grow more viscous with an increase of pressure.

The viscosity of water is generally made greater by dissolving other substances in it, and the larger the quantity of the solute the greater in general is the viscosity. Its viscosity would accordingly be expected to increase with the proportion of ice molecules. An increase of pressure by reducing their number would reduce at the same time the viscosity. An increase of temperature lowers the viscosity for the same reason, and very likely also by decreasing the viscosity of the mass of molecules of the second kind.

From the investigations of R. Cohen* it appears that the decrease of viscosity produced by a given increment of pressure is greater the lower the temperature. For instance, at 10°C. the effect of an increase of pressure of 600 atmospheres is about six times as great as at 23°C. This is to be attributed to the greater effect at 10° of the pressure in reducing the number of ice molecules. Moreover, when the temperature is constant, he finds that a given increase of pressure produces a greater effect upon the viscosity when the pressure already exerted is small than when it is larger. As an illustration, when the temperature is 15° an increase of pressure from 100 to 300 atmospheres produces a larger decrease in the viscosity than an increase from 300 to 600 atmospheres. The reason of this is to be found in the larger proportion of ice molecules present at low pressures and the consequent greater reduction in their number produced by the added pressure.

These results obtained by Cohen are of especial interest since they form the fulfilment of a prediction made by Roentgen "that the viscosity of water at high pressures will be less reduced by a given increase of pressure than at low pressures" and "that the effect referred to will for equal pressures be found to be the larger the lower the temperature of the water is."

Following the road marked out by Roentgen, a number of investigators have succeeded in finding the explanation

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* R. Cohen. *Wied. Ann.*, XLV, p. 666, 1891. "Einfluss des Druckes auf die Viscosität von Flüssigkeiten."

of some of the irregularities of water which he did not discuss. Hugo Witt* of Stockholm has applied the theory of ice molecules to several phenomena of aqueous solutions.

From the equation of equilibrium between the two kinds of water molecules in an aqueous solution, he infers that the presence of a solute has the effect of causing some of the ice molecules to change into those of the second kind. This at once explains why the volume of an aqueous solution is generally less than the sum of the volumes of the water and of the dissolved substance. The contraction is the result of the change of molecules of greater specific volume into those of less.

We have seen that an increase of pressure lowers the temperature of maximum density of water. Now both pressure and the presence of a substance dissolved in water have the effect of reducing the number of ice molecules, and hence it is seen why the temperature of maximum density of an aqueous solution is below 4° C.

Witt explains the high specific heat of water as due to the heat required to change the ice molecules into those of the second kind. Aqueous solutions nearly always have a lower specific heat than water. Even after making allowance for the solute, whose specific heat is of course less than that of water, it is found that the water in the solution seems to have a less specific heat than before the substance was dissolved in it. Witt attributes this to the solution's having fewer ice molecules than water, so that a rise of temperature of 1° will be followed by the transformation of fewer ice molecules and will therefore require a smaller quantity of heat. He finds in the heat requisite to change the ice molecules into the other kind a reason why the solution of substances in water is usually accompanied by a lowering of temperature.

When a solid is dissolved in a liquid there is a decrease in the vapor tension of the liquid. Raoult has shown how

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* Hugo Witt, *Öfversigt af Kongl. Vetenskaps-Akademiens Förhandlingar*, 1900, No. 1, p. 63. "Ueber die Constitution des Wassers."

to calculate this decrease. Now, when water is the solvent, Witt found that, even after allowing for the dissociating power of water, the observed lowering of the vapor tension is more than that calculated by Raoult's formula. He gives this explanation. There is reason to believe that the vapor tension of the ice molecules is greater than that of the others. The observed vapor tension of water probably lies between the two values. When a salt is dissolved in water, by its presence it occasions a lowering of the vapor tension; but in addition to this it causes some ice molecules to change into the second kind and thus the vapor tension is still further lowered. This last effect is not included in the formula of Raoult.

J. J. van Laar, of Utrecht,* in a mathematical paper reaches the conclusion that water is made up of $(H_2O)_2$ groups which dissociate with rising temperature. He explains the occurrence of a temperature of maximum density for water very much as Roentgen does. The contraction of volume resulting from the mixture of alcohol and water he accounts for thus: Both have complex molecular groups formed by association of the molecules represented by the respective chemical formulas, and in both cases change from the complex to the simple form is attended by a shrinking of volume. When the two liquids are mixed both lose in complex molecules and gain in simple ones. Hence the volume decreases. He calculates that the change of 18 g. H_2O into $(H_2O)_2$ causes a lessening of the volume by 8·4 cm^3.

In the experiments by Cohen referred to above it is shown that aqueous solutions of NaCl, which are not concentrated, suffer no change in viscosity by the application of a pressure of 600 atmospheres, at a certain temperature for each strength of solution. Below that temperature the viscosity is lessened; above it is increased. Now the behavior of water is the same† except that the temperature

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*J. J. van Laar, *Zeitschrift für physikalische Chemie*, XXXI, p. 1. "Ueber die theilweise Association der Flüssigkeiten."

† L. Hauser, *Drude's Annalen.*, V, p. 597, 1901. "Ueber den Einfluss des Druckes auf die Viscosität des Wassers."

of no effect is higher. We can find an explanation of this downward displacement of the temperature by recalling that, in accordance with the ideas of Witt and van Laar, the number of ice molecules in water at a certain temperature is the same as the number in a solution of salt in water at a lower temperature.

Within the past year a paper by Sutherland* has appeared in which a vigorous and successful attempt is made to furnish a quantitative explanation of the anomalies of water. The author aims to show that steam consists of H_2O, ice of $(H_2O)_3$ and water of a mixture of $(H_2O)_3$ and of $(H_2O)_2$. He calls H_2O hydrol, $(H_2O)_2$ dihydrol, and $(H_2O)_2$ trihydrol. According to this nomenclature Roentgen's ice molecules are trihydrol and his molecules of the second kind dihydrol. The chief results of the paper in the calculation of the physical constants of dihydrol and of trihydrol are given in the following table:

	Density, ρ_o, at 0° C.	$\rho_o = \rho_t (1 - kt.)$ Temp. Coeff. k.	Compressibility per Atmosphere at 0°.	Surface Tension at 0° in Dynes.
Dihydrol . . .	1·08942	·0009	·000016	78·3
Trihydrol . .	·88	·0002	·000010 (?)	73·32

	Critical Temperature.	Specific Heat at 0°.	Latent Heat of Fusion.	Latent Heat of Evaporation.	Viscosity at 0°.
Dihydrol . . .	368° C.	·8	—	257 cal.	·0030
Trihydrol . .	538° C.	·6	16 calories.	250 cal. approx.	·0381

The method of determining the density of one of the ingredients of water will now be given to serve as an example of Sutherland's manner of procedure. A curve is plotted in which the ordinates are the densities of water and the abscissas the corresponding temperatures. The curve has its maximum ordinate of 4° and then sinks toward the axis of X, appearing to approach a straight line asymptotically. It seems reasonable to take this straight line as giving the

* Sutherland, *Phil. Mag.* Series 5, Vol. L, p. 460, 1900. "The Molecular Constitution of Water."

density—temperature relations of one of the ingredients of water. Following the line back until it meets the axis of Y, the density at 0° is read off as 1·083. From considerations based on surface tension it is later shown that this ingredient is dihydrol.

Mendeléeff has calculated an equation giving the density of water as a function of the temperature. Sutherland throws this equation into a form in which the density is the sum of five terms. By regarding water at any temperature as a mixture of water having the composition which it possesses at 4° and of additional dihydrol, and further by assuming that both of these ingredients expand with heat in a similar and simple manner, he obtains another expression for the density of water at any temperature which also has five terms similar to those of the transformed Mendeléeff formula. From comparison of like terms of the two formulas it follows that the density of dihydrol at 0° is 1·08942, which agrees well with the value 1·083 found from the curve. It will not escape notice how much this result rests upon assumptions.

The following table shows the parts by weight of trihydrol in water at different temperatures under pressures of 1 and 150 atmospheres respectively.

t	0°	20°	40°	60°	80°	100°	120°	140°	198°
At 1 atmo. .	·375	·321	·284	·255	·234	·217	·203	·191	·165
At 150 " . .	·351	·300	·264	·237	·217	·203	——	——	——

It is calculated that at 2,300 atmospheres pressure there would be no trihydrol in water at 0°.

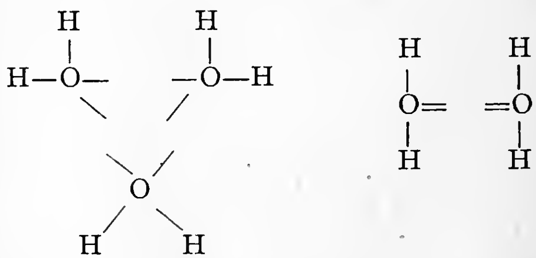
By Eötvös and by Ramsay and Shields it has been proved that for all normal liquids the temperature rate of change of a certain function of the surface tension, molecular weight and density of the liquid is the same and remains nearly constant almost up to the critical temperature. At temperatures below 40° water has this same constant provided the density and molecular weight of trihydrol, and not those of water as ordinarily understood, are taken. From 60° upward the same constant is approached if the density and molecular weight of dihydrol are used. Therefore up to 40° the surface layer of water

consists of trihydrol alone and beyond this dihydrol forms in greater and greater quantity with ascending temperature. The reason why the surface film differs in composition from the body of the water is that in the film tension manifests itself, and, if pressure converts trihydrol into dihydrol, then tension should produce the opposite change. Above 60°, however, the surface tension is so far reduced as to permit some dihydrol to form.

Sutherland says "The solubility of substances in trihydrol may be different from that in water." In connection with this the experiments of Jan von Zawidski * are of interest. He found that foam from aqueous solutions of acetic and of hydrochloric acids containing also some saponin was slightly richer in the acids than the body of the liquid, and that the difference of composition showed itself to a very marked degree in saponin solution by itself.

Sutherland regards the heat of fusion of ice as including the heat required to dissociate some trihydrol into dihydrol. This also holds for the specific heat of water. The latent heat of vaporization likewise includes the heat of dissociation of dihydrol into hydrol. It is calculated that 189 small calories are needed to change 1 gram of dihydrol into hydrol, at 100° and 177 to change 1 gram trihydrol into dihydrol at 0°.

Sutherland suggests these graphic formulæ for trihydrol and dihydrol in which o has valency of 4.



The hexagonal form of ice crystals seems to be the most probable grouping to be expected of molecules in which

* Jan von Zawidski. *Zeit. fur phys. Chem.*, XXXV, p. 77. "Zur Kenntniss der Zusammensetzung der Oberflächenschichten wässeriger Lösungen."

the equilateral triangle marked out by the three oxygen atoms is the chief feature.

The problem confronting Sutherland was this: Given a substance, whose behavior, especially as a liquid, is anomalous in a number of respects, to determine what must be the respective quantities, rates of change and physical constants of two simple and normal substances, by whose mixture the comportment of water shall be reproduced. Of necessity he often makes appeal to analogy with ordinary substances, for it is one of the conditions of the problem that the solution shall be in terms of such substances. Hypothesis often confronts the reader where he could wish for something firmer, yet the longer he reads the paper the surer he becomes that at last a scientific and quantitative explanation of the comportment of water exists.

G. Tamman * has found that in addition to ordinary ice there are two other varieties, II and III. They differ from the common kind in these respects.

(1) Their melting points are raised by the application of pressure, whereas the opposite is true of ordinary ice.

(2) Their density is greater than that of water. This accounts for the effect of pressure upon their melting points.

(3) They are formed only under special conditions of temperature and pressure. Common ice is cooled below —22° C. and the pressure raised to at least 2,400 kilograms per cm.^{2} Now if the temperature is further lowered until it is from —30° to —60° C. ice III forms; if it is lowered to —80° C. ice II forms.

When ordinary ice changes into ice II the following diminutions of volume per gram occur.

—73°	·171 cm.^{3}
—55°	·180
—34°	·193

The heat of transformation of common ice into ice II or ice III is positive or negative or zero according to the tem-

* G. Tamman, *Drude's Ann.*, II, p. 1. "Ueber die Grenzen des festen Zustandes," IV.

perature. The lowest temperature at which Tamman observed water and ice to exist together was —22·4° C., the pressure being 2,230 kilograms per cm.[2] He gives the following table of the temperatures at which ice is melted at the accompanying pressures.

—t°	·1°	2·5°	5·0	7·5°	10°	12·5°	15°	17.5°	20°	22.1°
Pressure kg. per cm.	1	336·	615·	890	1155	1410	1625	1835	2042	2200

It appears that the lower the temperature the less is the additional pressure requisite to produce a further lowering of the melting point by 1°.

When we reflect for how long a time air and water have been the objects of scientific investigation it is indeed remarkable that they both still richly repay re-examination.

I take the liberty of quoting here a paragraph in a letter from Mr. Hugo Witt to me. "It seems to me to be a great mistake first to study aqueous solutions and then other solutions. Water is, as I believe to have shown, and as Roentgen, van Laar and others believe (Professor Arrhenius believes also, he has told me, in the ice molecules) a very complicated substance, and there must in the process of solution in water be great exceptions from the simple rules which exist for other solvents that are not associated. And the chapter in treatises on physical chemistry, "Theorie der Lösungen' should rightly be entitled 'Theorie der Wässerigen Lösungen.'" Not only in the matter of solutions but in other more strictly physical relations it is a misfortune that the role of the typical liquid was assigned to water.

PHYSICAL SECTION.

Stated Meeting, held Wednesday, December 26, 1900.

NOTES ON MAGNETIC CURVES.

BY JESSE PAWLING, JR., B.S.

The following are solutions of examples 37, 38 and 39, page 51, of *Minchin's Statics*, Vol. 1, fifth edition.

"37. Given the base, $N\ S$, of a triangle $N\ P\ S$,* and also the sum of the cosines† of the base angles, $S\ N\ P$ and $N\ S\ P$; let the curve locus of P be constructed. Prove that if a particle be placed at any point of the curve and acted on by two forces, one repulsive form N and equal to

$$\frac{\mu}{N P^2},$$

and the other attractive toward S and equal to

$$\frac{\mu}{S P^2},$$

the resultant force is, at every position of the particle, directed along the tangent to the curve.

N. B.—This curve is called the "Magnetic Curve," being one of those in which small iron filings would arrange themselves under the influence of a fixed magnet whose poles are N and S.

It is to be observed that each little piece of iron is a magnet, having two poles at its extremities, and that it must therefore set at the point, P, where it is placed, in the direction of the resultant force on either of its poles."

To construct the resultant of the forces $N\ P$ and $N\ S$ acting at the point P on the curve $P\ S$, we take:

The force in the direction of $N P = P\ Q$

The force in the direction of $P\ S = P\ T$,

**Fig. 36* in the text. The accompanying figure is a modification of *Fig. 36*.

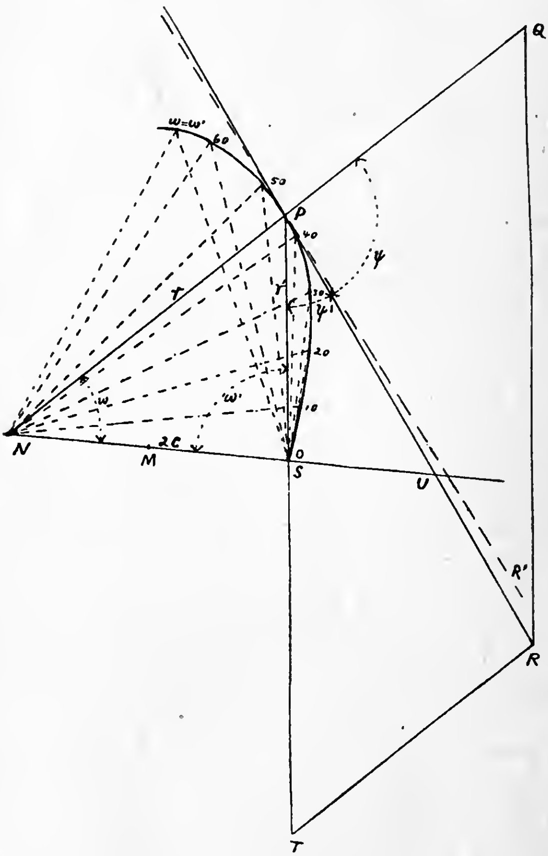
†The sum of the cosines is represented by

$$\cos \omega' + \cos \omega' = k$$

and, therefore, by the conditions of the problem,

$$P\,Q = \frac{\mu}{N\,P^2},\ P\,T = \frac{\mu}{S\,P^2}$$

Take a line of any assumed length and in this case this length;



A ______________ B

which we assume equal to $\mu^{\frac{1}{3}}$. Find the length of a line, l, a fourth proprotional by construction from the proportion,

$$\frac{l}{\mu^{\frac{1}{3}}} = \frac{\mu^{\frac{1}{3}}}{N\,P}$$

From which

$$l = \frac{\mu^{\frac{1}{3}}}{NP}$$

Taking l as a known term of a second construction by means of a fourth proportional, we have

$$\frac{PQ}{l} = \frac{\mu^{\frac{1}{3}}}{NP}$$

or, substituting the value of l

$$PQ = l\,\frac{\mu^{\frac{1}{3}}}{NP} = \frac{\mu}{NP^2}$$

In the same manner we find

$$PT = l'\frac{\mu^{\frac{1}{3}}}{SP} = \frac{\mu}{SP^2}$$

Take $\qquad QPR = \varphi$ and $TPR = \varphi'$

and $\qquad NP = r$ and $\quad SP = r'$

In the triangle PQR we have

$$\frac{PQ}{QR} = \frac{\sin PRQ}{\sin QPR}$$

and since $\qquad QR = PT$ and $PRQ = TPR$

the above becomes

$$\frac{PQ}{PT} = \frac{\sin TPR}{\sin QPR} = \frac{\sin \varphi'}{\sin \varphi}$$

Also

$$\frac{PQ}{PT} = \frac{\dfrac{\mu}{NP^2}}{\dfrac{\mu}{SP^2}} = \frac{SP^2}{NP^2} = \frac{r'^2}{r^2}$$

from which it follows that

$$\frac{\sin \varphi'}{\sin \phi} = \frac{r'^2}{r^2}$$

Also,

$$\varphi' + \varphi = QPT$$

These give two equations to determine φ' and φ.

Again:

$$\cos \omega + \cos \omega' = k$$

Differentiating

$$-\sin \omega - \sin \omega' \frac{d\omega'}{d\omega} = 0$$

or

$$\frac{d\omega'}{d\omega} = -\frac{\sin \omega}{\sin \omega'}$$

From the triangle $N S P$

$$\frac{\sin SNP}{\sin NSP} = \frac{SP}{NP} \text{ or } \frac{\sin \omega}{\sin' \omega} = \frac{r'}{r}$$

therefore,

$$\frac{d\omega'}{d\omega} = -\frac{r'}{r}$$

Assume that $P R'$ is a tangent, and that

$$N P R' = \varphi_1' \text{ and } Q P R' = \varphi_1 .$$

and it follows that from calculus,

$$\sin \varphi' = \frac{r\, d\omega}{ds} \text{ and } \sin \varphi_1' = \frac{r\, d(\pi - \omega')}{ds} = -\frac{r\, d\omega'}{ds}$$

and hence

$$\frac{\sin \varphi_1'}{\sin \varphi_1} = \frac{\frac{r'\, d\omega'}{ds}}{\frac{r\, d\omega}{ds}} = -\frac{r'\, d\omega}{r\, a\, \omega}$$

Substituting the value of

$$\frac{d\omega'}{d\omega},$$

we have

$$\frac{\sin \varphi_1'}{\sin \varphi_1} = \frac{r'^2}{r^2}$$

Also,

$$\varphi_1' + \varphi_1 = Q P T$$

These also give two equations to determine φ_1' and φ_1.

But these two equations for φ' and φ_1' are identical with those for φ and φ', hence

$$\varphi = \varphi_1 \text{ and } \varphi' = \varphi_1'$$

and $P R'$ is identical with $P R$.

That is, the resultant of the two forces $N P$ and $S P$ is tangent to the curve at P, which was to be proved.

"38. Prove that the line of action of the resultant force of a magnet on a magnetic pole at P divides $N S$ externally in the ratio $N P^3 : S P^3$."

In the triangle $P N U$

$$\frac{\sin N U P}{\sin N P U} = \frac{N P}{N U}$$

and in the triangle $P S U$

$$\frac{\sin S U P}{\sin S P U} = \frac{S P}{S U}$$

From these equations we have

$$\sin N U P = \sin N P U \cdot \frac{N P}{N U}, \quad \sin S U P = \sin S P U \cdot \frac{S P}{S U}$$

Now, since the angles

$$N U P = S U P$$

$$\sin S P U \cdot \frac{S P}{S U} = \sin N P U \cdot \frac{N P}{N U}$$

and, hence

$$\frac{N U}{S U} = \frac{N P \sin N P U}{S P \sin S P U}$$

But

$$\frac{\sin N P U}{\sin S P U} = \frac{\sin Q P R}{\sin T P R} = \frac{P T}{P Q} = \frac{N P^2}{S P^2}$$

Substituting this value in the above, we have

$$\frac{N U}{S U} = \frac{N P}{S P} \cdot \frac{N P^2}{S P^2} = \frac{N P^3}{S P^3}$$

which was to be proved.

"39. Iron filings are sprinkled over a sheet of paper on which a magnet rests; prove that all those filings which dip towards the same point on the line of the magnet lie on a circle (neglecting their mutual actions)."

If the filings dip towards the same point on the line of the magnet, the resultant force on the particle is directed along the tangent to the curve upon which the filings lie, and hence the tangents to the series of curves upon which these particles lie pass through a common point on the line of the magnet.

Let the point through which these lines pass be the point U. Now, we have just proved

$$\frac{NU}{SU} = \frac{NP^3}{SP^3}$$

and since U is a fixed point,

$$\frac{NP^3}{SP^3} = \text{a constant.}$$

or

$$\frac{r^3}{r'^3} = K^{\frac{3}{2}}$$

Taking the origin at the point M midway between N and S, and letting x and y be the coördinates of P, we have

$$r = \sqrt{y^2 + (c + x)^2} \quad , \quad r' = \sqrt{y^2 + (c - x)^2}$$

hence

$$\frac{\left\{ y^2 + (c + x)^2 \right\}^{\frac{3}{2}}}{\left\{ y^2 + (c - x)^2 \right\}^{\frac{3}{2}}} = K^{\frac{3}{2}}$$

or

$$\frac{y^2 + (c + x)^2}{y^2 + (c - x)^2} = K$$

From this, we have by reduction

$$y^2 + x^2 + 2c\,\frac{1 + K}{1 - K} + c^2 = O$$

which is the equation of a circle.

AN INVESTIGATION OF THE COST OF POWER.*

BY CLYDE D. GRAY.

PREFACE.

This investigation was undertaken in order to get a collection of reliable data on the production, cost and utilization of power by different methods. As far as the writer knows, there has been nothing published of this character and this attempt, although crude, may serve to give a slight insight into the subject.

In this investigation, complete files of the different engineering and technical periodicals were consulted as well as the transactions of the various engineering societies and the more important books relating to engineering in its many branches.

The writer has attempted to get the results of such tests and estimates as seemed reliable, to incorporate in the various tables given and has not tried to deduce any very specific conclusions, believing that the reader can best arrive at them in regard to any special case much better than if they were given by the writer. Such deductions as are given are, consequently, of the very broadest character.

The subject is a very broad one and the time given to it permitted only a brief review of the material that might have been used.

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When reference to any of the above periodicals is made in the body of the thesis, the initials of the periodical only are given and the volume and page on which it is found, thus: S.R.J. 1^{3}, 353, would be the *Street Railway Journal*, Vol. XIII, page 353. When the volume and page are not given, it is usually stated in what year and month the article referred to is found.

MAN POWER.

The power exerted by a man is variable and depends upon the individual to a large extent. His endurance and habits of life enter into the matter as well as the climatic and other conditions surrounding him. On account of all these variable factors, it is difficult to get a very close estimate of the power which he is able to produce.

In the *Trans. A.S.M.E.*, vol. VIII, p. 714, Dr. Thurston says that, on the average, a man exerts about ·1 horse-power. Rankine in his book, "The Steam Engine," p. 84–86, gives the power of a man on a crank as ·1 that of a horse on a cart, or ·125 that of the same horse working on a gin. In the discussion of the above paper, Mr. O'Neill mentioned a case of a man doing ·75 horse-power on a crank for short periods of time.

An abstract from the *Sci. Am.* in "Eng. News" for May 2, 1885, gives some figures on the power exerted by old men ascending stairs. One, 63 years old, exerted ·353 horse-power. Another of the same age produced ·231 horse-power. A third, 69 years of age, used ·276 horse-power, while a fourth, 72 years old, exerted ·222 horse-power.

In "The Animal as a Machine," Dr. Thurston gives the thermo-dynamic efficiency of a man as 20 per cent., which is about the same as that of the best steam engine. In respect to weight per horse-power, a man has 600–700 pounds as compared with the 1500–2000 pounds of the horse, or the 50–100 pounds of the bird. Mr. Box gives the power of a man, working ten hours per day on a winch, as ·072 horse-power, on a treadmill as ·105 horse-power and on a capstan, ·084 horse-power. If the hours of labor are reduced from 10 to 4 per day, then in the above cases the power will be increased to ·113, ·167 and ·134 horse-power respectively, thus showing the large increase of power as the time of labor is shortened. Mr. D. K. Clark says that the average man working on a pump, winch, or crane, exerts about ·1 horse-power if the day consists of ten hours, but that he can produce four or five times this amount if the time is shortened.

Rankine gives the following table for the power of a man doing different kinds of work:

	Hours Per Day.	Horse-Power.
Raising his own weight up stair or ladder	8	·1320
Hauling up weights with rope, lowering it empty . . .	6	·0545
Lifting weights by hand	6	·0440
Carrying weights up stairs, returning unloaded . . .	6	·0337
Shoveling earth to height of 5 feet 6 inches	10	·0142
Pushing or pulling horizontally	8	·0965
Turning a crank or winch	8	·0820
Working a pump	10	·0600

Assuming ·1 horse-power as the power of the average man, then, if labor can be procured for $1 per day of ten hours, a horse-power hour will cost $1; a horse-power year, assuming 3,000 hours per year, will cost $3,000, which is greatly in excess of any other kind of power. Another disadvantage of human power is that it cannot be worked continuously, but must have long periods for rest and recuperation. It also requires a large amount of space for a small amount of power as compared with other sources of power.

The absurdity of using man-power in place of steam or other similar sources may be shown by the following figures: Consider that 50,000 horse-power are needed for any purpose. If men are to be used, there will have to be three shifts, each working for eight hours per day and if each man can exert ·1 horse-power, it will require 50,000 x 10 x 3, or 1,500,000 men, or the equivalent of the population of a large city to produce the same amount of power as one plant. Consequently this kind of power is limited to purposes in which the use of the mind as well as that of the body is required and for such other purposes as can best be accomplished by its use regardless of cost.

ANIMAL POWER.

In the preceding chapter on human power, it was seen that man has certain limitations in regard to length of time in which he can work, etc. These apply equally well to the case of animals.

Mr. Box, in a table found in Thurston's "The Animal as

a Machine," p. 52, gives as the power of a horse working ten hours a day on a capstan ·477 horse-power, that of a mule, ·315 horse-power, of an ox, ·423 horse-power and that of an ass, ·131 horse-power, while if the hours of work are reduced to four per day, the power would be raised to ·75, ·501, ·669 and ·184 horse-power respectively.

Rankine gives as the work of a horse:

	Hours Per Day.	Horse-Power.
Cantering or trotting on light railway car	4	·815
Drawing cart or boat (walking)	8	·785
Drawing gin or mill (walking)	8	·546
Drawing gin or mill (trotting)	4·5	·780
Average		·785

The following table has been compiled from figures of Rankine and Box. Those of Box, from the section above and the others from Kent's Handbook, p. 435. The values are given in horse-power and also in percentages of the power of the average draught-horse.

	Rankine.		Box.	
Animal.	Horse-Power.	Per Cent.	Horse-Power.	Per Cent.
Horse	·785	100·0	·477	100·0
Ox	·660	84·1	·423	88·6
Mule	·500	63·7	·315	66·1
Ass	·250	31·9	·131	27·5

It seems from the above values that the horse-power as commonly used, 33,000 foot pounds per minute, is too large when compared with the actual work of the average horse; but it serves its purpose as a means of comparison of the values of different kinds of power just as well as though it were correct.

The cost of a horse-power year will be approximately as follows for a year of 3,000 hours:

Cost of horse	$150.00
Cost of harness	20.00
Total investment	$170.00
Interest, 5 per cent. Depreciation, etc., 15 per cent. Total 20 per cent.	$34.00
Feed and stabling, $0.25 per day for 300 days	75.00
Driver for two horses, at $1.50 (·5 x 1·50 x 300)	225.00
Total yearly expense	$334.00
Cost of 1 horse-power year, assuming horse, ·75 horse-power,	$446.00

The above estimate is very conservative and does not include charges and repairs on wagons, or insurance on horse and equipment.

In the *Transactions of the A.I.E.E.*, vol. XVI, p. 485, some figures are given by Messrs. Lever and Fleiss, comparing the cost of delivering goods in New York City by means of horses and electrically-driven wagons. They made a very careful series of tests of both methods and found that the cost per ton-mile of the motor-driven carriage was $0.0425 as against $0.102 for a two-horse heavy delivery wagon, thus making a saving for the motor of $0.0595 per ton-mile. The motor did the same amount of work in about two-thirds the time required by the horse.

The use of horses in traction work on street railways will be taken up later in comparison with other kinds of motive power.

WIND POWER.

The power of the wind can be easily and cheaply utilized for certain purposes, especially for the pumping of water and for such other uses where close regulation is not required. The greatest disadvantages of this kind of power are its irregularity and the difficulty of governing for a constant speed. The latter has prevented the extensive use of wind motors for electric lighting and the production of power to be transmitted electrically to machines. Nevertheless, by the use of storage batteries, these troubles have to a certain extent been eliminated, so that now it is perfectly feasible to do electric lighting and to furnish steady power for other purposes.

The power exerted by windmills depends upon the size of wheel, the velocity and regularity of the wind. The power of the best grade of mills is directly proportional to the square of the diameter and inversely as the revolutions per minute and increases directly as the square of the proportional velocity of the wind; *i. e.*, if the velocity is doubled the power is quadrupled. The modern mill of medium and large size will run in a 4-mile breeze, becoming very efficient in an 8 to 16-mile breeze and will run with safety up to a 45-mile gale. (Above taken from an article

in the *Iron Age*, based upon the observations of the U. S. Signal Service. See Kent, p. 497.)

Mr. A. R. Wolff in the *Trans. A.S.M.E.*, vol. III, p. 301, also given in Kent, p. 496, has a table concerning the power that is developed by different sizes of windmills and also the cost of power produced by them. The article in *Iron Age* mentioned above also gives some figures on the horse-power of wheels. The data are reproduced in the table below:

	D. H. P.			Cost.	Cost.	Gal. pumped
Diam.	Wolff.	*Iron Age.*	Cost Mill.	H. P. hr.	H. P. yr.	100 feet per min.
10	·12	·15	175	$0.058	$169	4·75
16	·41		671	0.059	172	16·15
20	·78	1·00	993	0.045	131	31·25
25	1·34	1·75	1197	0·032	93	49·72
30		3·50				
40		7·50				
50		12·00				

The above is based upon a 16-mile wind for eight hours per day, which has been found from practice to be nearly correct.

The application of the windmill to electric lighting was tried by Mr. C. F. Brush, at Cleveland, O. and found to work very well. He used a storage battery of 408 cells, connected in 12 parallel-series having a constant capacity of 100 16-candle-power lamps. The mill was 56 feet in diameter and drove a dynamo at 500 revolutions per minute, having an output of 12 kilowatts at 70–75 volts, the regulation for charging the battery being automatic in its action.

Lieut. I. N. Lewis, in *Eng. Mag.* for December, 1894, describes a small lighting plant that was substituted for a steam plant and gives some figures in regard to the relative economy of the windmill when compared with the steam engine. These are given below:

	Steam.	Wind.
Number of lights	75	127
First cost	$1,000	$1,800
Depreciation	100	130
Interest	50	90
Operating expenses	100	10
Attendance	75	20
Total yearly cost	325	250
Cost per lamp year	4.33	2.00

It may be seen from the above figures that the cost of lighting by the use of wind power is less than one-half that by the use of steam.

Another method of storing energy produced by wind power would be to use the mill to pump water into an elevated tank from which it could be drawn and discharged through a water-wheel, preferably of the tangential type. The water-wheel could be belted to a dynamo or other machinery which it is desired to drive. This scheme seems very feasible, especially where water storage is needed for other purposes, as the mill could be set to run continually and keep the tank full. In this way, the tank would take the place of the storage battery and would need less repairs and attention as the complications, which would arise in the regulation for charging, would be absent. The capacity of the tank need not be so very large, one having a sufficient storage for twenty-four hours steady running of the plant being large enough for all practical purposes.

In order to make this plan clear, a hypothetical case is figured out below that will serve to show what might be done in this way. Suppose it was desired to light a private residence that had no means of getting electrical power from city or town mains and there was no water power available for the work, but enough water for its utilization in the tank-storage plan. There would be left steam, gas or wind power, any one of which might be used for the purpose. The steam and gas engine would probably give about the same results and the cost would be approximately the same unless steam was needed for heating or other purposes about the place. In the latter case, the steam would be the cheaper to use, for the same boiler could be used for both purposes; but on the other hand, the gas engine would need scarcely any attention while running and so it is likely that the cost of steam and gas power would about balance. From the comparison of costs in Mr. Lewis' paper, it is evident that the windmill is much the cheaper source of power for this use.

Suppose that about 75 16-candle-power lights are to be the maximum load. Then a 4-kilowatt dynamo would be

large enough to furnish current for them. Assuming 80 per cent. efficiency of the dynamo, the power needed at the pulley would be 4 ÷ 8 × ·746, or 6·67 horse-power, or say 7 horse-power at the water-wheel, which would be ample to cover all loss in the belt. If the efficiency of the water-wheel is 75 per cent., which is a very conservative figure for wheels of this class, the power in the water at the jet must be about 9·5 horse-power, or 9·5 x 33,000 or 314,000 feet pounds per minute, and if the tank is elevated so as to give an effective head of 100 feet, it would need 3,140 pounds of water per minute to furnish the power. Allowing for the friction in the pipes, a 10-horse-power mill would probably be large enough to furnish the wheel with water continuously.

It is probable that not more than one-half of the lamps will be turned on at any time and then they will be used not over four hours per day, on the average. In this case, since the efficiency falls off with the load, the power needed at the jet will be 6 horse-power, or 1,980 pounds of water per minute, and in four hours, 1,980 x 4 x 60, or 4,750,000 pounds of water per day that would have to be pumped into the tank. From the table it is found that a 30-foot wheel will develop 3·5 horse-power with a 16-mile wind, on an average of eight hours per day and hence it would pump (3·5 x 33,000 x 60 x 8) ÷ 100 or 554,000 pounds into the tank which is more than needed to supply the forty lamps for four hours per day. The tank should be large enough to hold water for two or three days' run as the wind is a very uncertain means of power. In case it should be desirable to always have power it might be advisable to have a small gas engine that could be used in case of a long interval of calm weather.

The cost of installing such a plant and the fixed and operating expenses are hard to estimate; but an attempt has been made in the following calculations:

Cost of mill, tower and pump	$1,500
Cost of tank, dynamo and wheel	900
Cost of piping	100
Total cost of plant	$2,500

Interest at 5 per cent. on $2,500	$125
Depreciation on mill at 5 per cent.	75
Depreciation on tank and machinery	50
Attendance and operating expenses	50
Total yearly cost	$300
And on the basis of 6 horse-power a horse-power year would cost,	$50
or for seventy-five lamps, a lamp year would cost	4

This estimate is very conservative and the costs could probably be reduced 50 per cent. in some cases. The item of cost of tank would be reduced if the water from it were used for other purposes, also if it could be built on a hill so that it would not have to be raised on a tower for the sake of getting the head. For small work, the tank and mill could be supported on the same tower, thus saving in first cost. The item of attendance could be reduced to a very small amount if the plant were close to the house, so that one of the men employed about the house or barn could look after it. If it were situated in a section of country where the water was used for irrigating purposes, the water, after passing the wheel, could be used in the usual manner for irrigation.

WATER POWER.

Water is a very cheap and easily controlled means of producing power, especially in sections of country where it is available and where coal is high in price, so that it pays to transmit power electrically to great distances.

There are two classes into which water-power can be divided: One where a large quantity of water is available, but having a small head, the other, in which a small amount of water is at hand, but with a considerable head. The first applies to the eastern part of the United States in general, while the other is used more in the mountainous sections of the West, where fuel is expensive. Thus the turbine class of water-wheels is more generally used in the East and the tangential or impulse type in the West.

Some of the more important water-power plants in this country are given in the table following:

TURBINE WHEELS.

	Horse-Power.	Head Ft.	Kind of Wheel.
Butte, Mon.	4,000	58	Leffel, Niagara type.
St. Croix, Wis.	4,000	82	Victor horizontal.
Stuyvesant Falls, N. Y.	3,300	40	Victor.
Montmorency, Can.	5,000	260	Victor high pressure.
Hartford, Conn.	3,000	29	Horizontal.
Niagara, N. Y.	50,000	180	Vertical.

IN PROCESS OF CONSTRUCTION.

	Horse-Power.	Head Ft.	Kind of Wheel.
Richmond, Va.	11,000		
Shawanigan, Can.	75,000		
Sault Ste Marie	50,000	17	Horizontal type.
Messena, N. Y.	75,000	35·5	Victor horizontal type.

TANGENTIAL WHEELS.

	Horse-Power.	Head. Ft.	Kind of Wheel.
Big Cottonwood	2,400	370	Pelton, 61-inch.
Ogden, Utah	5,000	450	Knight.
Utah Station of Utah Co.	2,000	450	Pelton.
Blue Lakes	2,700	1,040	Doble.
San Bernardino, Cal.	4,000	700	Pelton, 82-inch.
Snoqualmie Falls, Wash.	8,000	270	Doble.
Colgate, Cal.	15,000	700	Risdon.

The above tables may serve to show to what an extent water-power is being used in this country. It is especially useful where the power can be transmitted to mines or for other power purposes in sections of the country where coal and transportation charges are high. In the East, the water-powers are being developed for manufacturing and electrolytic purposes, because they are cheaper and cleaner than steam power. Another reason may be that a large amount of power can be produced in a single plant, as at Niagara Falls, and transmitted many miles for application in neighboring cities.

The old forms of over-shot, under-shot and breast wheels are not used to any great extent at the present time as their efficiencies are low when compared with the two types of modern wheels universally in use to-day. Mr. A. F. Guy, in his book "Electric Light and Power," gives the efficiency of over-shot wheels from 50 to 70 per cent., breast wheels from 45 to 50 per cent. and under-shot, from 27 to 30 per cent. Emerson says that over-shot wheels have been known

to give 75 per cent. efficiency, but the average performance is not over 60 per cent. (Kent, p. 596.)

In regard to the tangential class of wheels, some tests have been made upon them and the principal results are given in the table below:

TANGENTIAL WHEEL TESTS.

Kind.	Size. Inch.	Horse-Power.	Head. Feet.	Efficiency. Per Cent.	Authority.
Pelton . .	60	107·0	384·7	87·30	Browne, *Eng. News*, F. '92.
Pelton . .	12	1·9	230·0	80·00	
Cascade .	38	15·1	164·1	91·02	Cooper, F. In. v. 143–376.
Cascade .	26	9·5	163·4	91·85	
Cascade av.,	38	13·8	159·2	88·65	
Cascade av.,	26	14·8	164·7	88·28	

There has been a considerable amount of testing on small wheels of this type in the Sibley College laboratories and efficiencies ranging from 65 to 90 per cent. and over have been found, with the average about 80 per cent. It is safe to assume the efficiency of large wheels of this class, between 85 and 90 per cent, and that of smaller wheels between 75 and 85 per cent.

The turbine class of wheel is of the greatest importance in this section of the country and a table of tests is given below, embodying some of the most extensive and carefully conducted tests that have ever been made, the Centennial tests of 1876 and some made at Holyoke, Mass., at which place there is a special laboratory for such work.

TURBINE TESTS.

Wheel.	Efficiency. Per Cent. Full.	Three-fourths.	One-half.	Authority.
Risdon	87·68	82·41	75·35	Centennial tests, Kent, p. 596.
National . . .	83·79	70·79		
Geyelin . . .	83·30			
Tait	82·13	70·40		
Goldie & McC.,	81·21	55·90		
Hunt Mch. Co.,	78·70	68·6		
Tyler	79.59	79·92	69·59	
Geyelin . . .	77·57			
Knowlton . .	77·43			
Cope & Sons .	76·94			
Barber & H. .	76·16		71·14	
York Mfg. Co.,	75·70	67·57		
Mosser & Co. .	75·15	70·52	66·04	

Wheel.	Efficiency. Per Cent. Full.	Three-fourths.	One-half.	Authority.
Sampson, 45″	82·03	83·68	75·95	Leffel catalogue. Test in 1897.
Sampson, 35″	81·04	83·88	76·19	
Boyden, 81″	79·37	76·18	64·90	Thurston, A.S.M.E, 8–359. Holyoke tests.
Hercules	80·50	73·78		
New American,	79·50	73·20		These figures for full load and for three-fourths load are averages from three-fourths to full and from one-half to three-fourths.
Success	78·60	70·80		
Tyler	76·60	65·50		
Tait	74·40	68·00		
Thompson	72·10	69·60		
Nonesuch	71·20	61·90		
Houston	71·70	39·70		
Burnham, 36″,	81·82	70·78	75·26	
Hercules, 45″,	80·70		74·40	Aldrich, A.S.M.E., 15–705.
Collins	83·50			S. Webber, *Eng. Mag.* 1–335.
Fourneyron	72·50			
Boyden	78·00			
Howd	79·00			Same. Francis' test in '51.
Swain	84·00			Same. Francis' test in '59.
Collins, 60″	79·70	78·70	65·20	Bodmer in "Hydraulic Motors, Turbines and Pressure-Engines," p. 387.
Collins, 60″	83·78	with draft-tube and cone.		
Collins, 60″	84·34	with tube alone.		
Boyden	80·17			
Hercules	85·80	87·00		
Collins	85·06	83·27	74·64	
Victor	85·98	76·00		Holyoke test in 1895.

From the above table, it may be seen that there is a considerable variation in the efficiencies of turbine water-wheels. 87·68 per cent. is the highest in the list, but there is room for doubt in this case, as there are no records of more recent tests that show over 86 per cent., while there are many that show from 85 to 86 per cent. Kent says that the limit of turbine efficiency is about 86 per cent. and that 75–80 per cent. is very good. (Kent, p. 594.) Emerson says that in tests made at the Philadelphia water-works in 1859–60, on eighteen wheels, one gave less than 50 per cent., two between 50 per cent. and 60 per cent., six between 60 per cent. and 70 per cent., several between 71 per cent. and 77 per cent., two 82 per cent. and one 87·77 per cent. The last figure is rather high and may be doubted. Weisbach says that the limit of efficiency is 88 per cent.

It is safe to take the efficiency of good modern wheels at

from 80 per cent. to 85 per cent., under any head for which they are designed. There are several American manufacturers of turbines who will guarantee an efficiency of 80 per cent. from three-fourths to full load, and in some cases as high as 85 per cent. In general, the efficiency does not fall off a great deal for three-fourths load and in some cases of modern wheels it is higher at three-fourths than at full load.

The costs of water-power plants are widely different, depending upon the location, size and extent of the hydraulic works needed, length of penstock and flume and many other things that differ in the various localities. Below are given some figures in regard to the costs of plants. These are low-head plants fitted with turbine wheels and are used principally for mill or factory purposes. The costs do not include costs of dam unless so specified, but include everything else in the plant. The horse-power basis upon which they are figured is the horse-power delivered at the wheel shaft.

WATER-PLANT COSTS.

Place.	Cost per D. H. P.	Authority.
Lawrence, Mass.	$68 67	Manning, A.S.M.E., vol. 10–499.
Manchester, N. H.	66 00	Manning, A.S.M.E., vol. 10–499.
Lowell, Mass., 13 feet head	110 00	C. T. Main, A.S.M.E., vol. 11–108.
Lowell, Mass., 18 feet head	57 00	C. T. Main, A.S.M.E., vol. 11–108.
Lawrence, Mass.	63 00	C. T. Main, A.S.M.E., vol. 11–108.
Lawrence, Mass., 1,000 H. P.,	67 50	C. T. Main, A.S.M.E., vol. 11–108.
Concord, N. H. (with dam)	57 75	Webber, A.S.M.E , 17–41.
Augusta, Ga.	34 20	Webber, A.S.M.E , 17–41.
Columbia, S. C.	37 50	Webber, A.S.M.E , 17–41.
Caratonk Falls, Me. (dam)	24 00	Webber, A.S.M.E , 17–41.
Omaha, Neb. (estimate)	67 33	*Eng. Mag.*, vol. VII, p. 409.
Zurich (with dam)	100 00	*Eng. Mag.*, February, 1900.
Paderna, Italy (with dam)	120 00	*Eng. Mag.*, February, 1900.
Big Cottonwood, 3,000 H. P.	108 25	*Eng. News*, October 1, 1896.
Average without dam	53 41	(Excluding Lowell, $110.)
Average with dam	79 55	

It is probable that the cost of such plants will be from $40 to $60 excluding the cost of dam, but including all other parts and when the dam is included that it will be from $60 to $100. Webber, in *Iron Age*, February and

March, 1893, says that water-power plants can be put in for $100 per horse-power and Stilwell, in A.I.E.E., 10–484, says that the cost may be as low as $65.

The cost of water-power per horse-power year is variable, depending, as it does, upon the first cost of plant and hence no very good average can be found. The table given below may serve to show the costs in some cases that have been reported.

COST OF WATER-POWER.

Place.	Cost per H. P. Yr.	Authority.
Lawrence, Mass.	$13 70	C. T. Main, A.S.M.E., 13–140.
Canada (lowest)	6 25	Meyer, *Sci. Am.*, February 9, 1882.
Cottonwood	16 10	*Eng. News*, October 1, 1896.
Lawrence, Mass., 1,000 H. P.,	22 62	Manning, A.S.M.E., 10–48.
Lawrence, Mass., 500 H. P.	19 13	Main, A.S.M.E., 13–140.
Concord, N. H.	8 64	Webber, A.S.M.E., 17–41.
Augusta, Ga.	11 05	Webber, A.S.M.E., 17–41.
Columbia, S. C.	9 50	Webber, A.S.M.E., 17–41.
Omaha, Neb. (estimate)	8 08	*Eng. Mag.*, vol. VII, p. 409.
Norway (electrolytic work)	11 25	*Chem. Ind.*, vol. XXIII, p. 121.
Niagara (sold for)	13 00	Emery, A.I.E.E., 12–358.
Estimate on plant	5 42	Webber, W. O. *Eng. Mag.*, 15–926.
Average of the above	10 72	

From the above table it may be seen that the cost per horse-power year is $10.72. Webber gives it as $10 to $12. (*Iron Age*, February and March, 1893) and Conant, in an article in the *Street Railway Journal* for October, 1898, gives the cost as ranging from $10.40 to $22.40. A fair average may be taken as varying from $10 to $15.

Water-power has its disadvantages as have other kinds of power, and among them may be mentioned the effect of drouth, unless there is a very large storage capacity for water, which, if it is provided, greatly increases the first cost so that it is often cheaper to install steam-power to be used in emergencies of this kind. Another great disadvantage, which is being overcome rapidly since the use of water-power has taken such rapid advances in the last few years, is the difficulty of governing the speed of the wheels. A few years ago it was impossible to use turbines on any kind of work that required reasonably good regulation for

a constant speed and the question of using them to drive electrical machinery was scarcely thought of; but now they may be regulated so as to give fairly good regulation even for such exacting service as electric lighting and the running of alternators in parallel. In some sections of the country where there have been good water-power plants, the water is failing on account of the cutting down of the forests on the section of country dependent upon for supply. This will have to be met by the increased amount of storage needed to carry the plant over the dry seasons, which may be so expensive to build that the plants may be abandoned, or else steam or other power put in as an auxiliary. This question of gradually failing water supply should be carefully looked into before any large investment in a water-power plant is made.

The cost of attendance of water-power plants is less than that of steam or other plants and, on account of the absence of a fuel bill, the operating expense is very small; but on the other hand the first cost is large and therefore the fixed charges are correspondingly greater than with other kinds of plants. The depreciation and repair bill is less than the case of steam, an allowance of 4 per cent. usually being considered ample to cover these items, while the corresponding allowance for a steam or gas engine plant is 10 per cent. to 15 per cent.

STEAM POWER.

Perhaps the best-known and most extensively used source of power is the steam engine, which has come into use almost entirely within the past century. From the humble beginnings of Newcomen and Watt have developed the great engines of Corliss, Leavitt, Reynolds, Nordberg and many others of the same class. This development was necessarily slow and was a gradual refinement and perfecting of details until the present almost perfect type of engine was evolved. It is a question whether the present type of steam-engine will be improved very much in the future. If so, the advance will be along the line of the employment of higher steam-pressures together with the

use of superheated steam. The tendency is in this direction at the present time and it is possible that by such methods, with a further use of the steam turbine for certain purposes, the efficiency of the steam engine may be slightly increased.

It may be assumed for all practical, purposes in which a reasonable amount of safety for persons and property is desired, that the existing range of pressure and hence the limit of efficiency, which is very closely dependent upon the pressure, has been reached in the average case. This being the case, the limits of the use of the steam engine and the cost of its operation for different purposes are well known and the cost of operation and maintenance can be estimated very closely from the results of tests and other data that has been made public.

As the steam engine depends upon the fuel which is used in the boiler furnace for its working substance, it is fitting that a little space should be given to the various kinds of fuel in use under boilers, considering their relative values as steam producers and the cost of power as modified by the item of expense of fuel. Coal is the fuel used to the greatest extent for this purpose, although wood, peat, oil, straw, sawdust and other materials are used in limited amount.

The table below contains the calorific values of coals from different sections of the country.

CALORIFIC POWER OF COAL.

Locality and Kind.	B. T. U. per lb.	Authority.
Colorado, all kinds, 6 samples	14,500	Poole, "Calorific Power of Fuel."
Illinois, all kinds, 51 samples	13,300	
Indiana, all kinds, 6 samples	14,160	
Maryland, all kinds, 1 sample	13,438	
Ohio, all kinds, 17 samples	14,392	
Pennsylvania, anth., 21 samples	14,110	
Pennsylvania, bit., 28 samples	14 951	
W. Va., Pocahontas, semi-bit.	15,739	
W. Va,, average, all kinds	13,000	
American anthracite, average	14,833	Thurston, "Steam Boiler," p. 195.
American bituminous, average	14,796	
Anthracite, average	14,400	Morin and Tresca.
Bituminous, average	13,500	

Locality and Kind.	B. T. U. per lb.	Authority.
Cumberland, Md., George's Crk.	15,141 14,085	Barrus, A.S.M.E., 14–816.
Pocahontas, Va., 5 tests . . .	15,086 14,507	
New River, Va., 6 tests	14,696 14,427	
Youghiogheny, Pa., lump	13,752	
Youghiogheny, Pa,, slack . . .	12,988	
Anthracite, 11 tests	14,509 12,873	
Anthracite	14,446	Average of Poole, Thurston, Morin and Tresca.
Bituminous	14,873	Av. of Poole and Thurston.

By the inspection of the above table it is seen that the bituminous coal is slightly the better of the two classes on the average. The values differ greatly with the locality, but samples from the same place do not differ greatly and hence one can tell approximately the value if he knows from where it came. For further information in regard to coal see Kent and also Poole's "Calorific Power of Fuel."

If the chemical analysis of a sample of coal is known, it is easy to calculate its heating value from the formula of Dulong:

$$\text{Heating power in B.T.U.} = 14{,}500\,C + 62{,}500\left(H - \frac{O}{8}\right)$$

in which C, H and O are the proportions of carbon, hydrogen and oxygen in the coal. The results given by this formula are very near the values found by calorimetric tests as shown by the work of Mahler. (*Mineral Industry*, vol. I, p. 97.)

Kent has made up a table based upon the results of Mahler's tests, from which the value of any coal can be calculated to within 3 per cent., if the proximate analysis of the coal be known. This table is given in his handbook, p. 634.

Oil is the fuel that is perhaps used to the greatest extent after coal, and a few values are given in the table:

OIL VALUES.

Kind and Locality.	B.T.U. per lb.	Authority.
Heavy petroleum, W. Va. .	18,324	Poole.
" " Pa. . . .	19,210	"

Kind and Locality.	B. T. U. per lb.	Authority.
Heavy Petroleum, Pa. . . .	20,736	Poole.
" " W. Va.	18,200	Thurston, "Steam Boiler," 180.
Light " "	18,400	Poole.
" " Pa. . . .	17,930	"
" " W. Va.	18,350	Thurston,
" " Pa. . .	18,050	"
Heavy " Ohio . .	18,718	Poole, "Cal. Power of Fuel."
" " " . . .	18,450	Thurston,
" oil, Pa.	19,241	Poole.
" " W. Va.	18,184	"
Petroleum, Pa.	20,360	Thurston,
" "	20,746	Barr, "Combustion of Coal."
" refuse	19,832	Favre and Silbermann.
Heavy crude oil, Pa.	20,736	" " "
Wyoming, average	19,400	Poole.
Europe	18,000	Thurston.

From the above, the value of heavy Pennsylvania petroleum may be taken as about 20,000 B.T.U. per pound and that of the light as 18,000 B.T.U. per pound, while the Ohio oils are about 18,500 B.T.U. per pound in value and those from West Virginia have a heating value of about 18,300 B.T.U. It is safe to assume that the average heating value of American oils is in the neighborhood of 18,500 B.T.U. per pound.

[*To be continued.*]

STORING PETROLEUM UNDERGROUND.

Apropos to the extended discussion growing out of the late very destructive petroleum tank fire at Point Breeze, Philadelphia, the following item concerning the dangers arising from storing petroleum in underground tanks appears to be important:

A firm in the London suburbs had twenty-five of these underground tanks filled with petroleum. The system of discharging water through five separate intercepting chambers was conceded to thoroughly extract all but the smallest portion of the spirit. A heavy storm broke over the district during the afternoon, and the sewers failed to cope with the heavy rush of storm water. Consequently a large amount of water found its way to these tanks and washed away from three of them the puddling clay with which they were sealed. A large quantity of spirit was thus liberated. The storm was followed by a fire in the vicinity of the petroleum tanks, and while the firemen were engaged in its subjugation the petroleum flowing through the streets with the superfluous water exploded with terrific violence. Four persons lost their lives and several were injured. Fortunately the concussion did not disturb the other tanks, otherwise an appalling catastrophe would have ensued.

W.

ELECTROLYTIC SODA AND BLEACH.

The Hargreaves-Bird process for producing soda and bleach electrolytically is now in operation on a commercial scale at Middlewich, in Cheshire, England, and the products are finding a ready market. At the present time fifty cells, of the type described in the *Mineral Industry*, vol. VI, are at work, and the daily capacity is about nine tons of bleach and thirteen tons of soda crystals, though the soda output is not marketed solely as crystals. Another set of fifty cells is in course of erection, and further extensions will be proceeded with as the products become known. The Electrolytic Alkali Company has always exhibited caution in conducting its business, and its policy has been to refrain from suddenly increasing the supply of these products. Thus it does not upset the chemical market nor make violent fluctuations in the price.

An incidental advantage of this process is that the bleach obtained keeps absolutely dry. There is no hydrochloric acid about to form calcium chloride, which is always found in Leblanc bleach. Another point of interest is that the soda crystals average 99 per cent. in purity, the remaining 1 per cent. consisting of sodium chloride, sulphate and sulphite of soda. This small proportion of sulphate and sulphite is due to the presence of sulphur in the carbonating gases. Brunner, Mond & Co., who use the ammonia-soda process have recently pointed out that there is a good deal of soda placed on the English market by English and Continental producers that contains over 25 per cent. of sulphate of soda and in some cases even a greater percentage than that. These crystals are presumably made by the Leblanc process, and the black ash process must be imperfectly carried out with a view of lowering the cost of production. Brunner, Mond & Co. claim a percentage of 98·25 for their soda crystals, not quite so high as the figure given by the Electrolytic Alkali Company, but still high enough for all purposes for which soda crystals are used.—*Engineering and Mining Journal.*

LANTERN SLIDES SHOWING STEREOSCOPIC RELIEF.

The desirability of making lantern-slide projections—landscapes, buildings, portraits, etc., so as to give the effect of natural relief, is universally admitted, but thus far no single method of accomplishing the object has been suggested. The superposition of two pictures of the same subject on the slide, one outlined in red and the other in blue, which when projected on the screen are slightly "out of register," and which are examined through specially prepared spectacles of red and blue glass affords perhaps the simplest way of accomplishing the result, but the method is nevertheless complicated.

Another ingenious optical artifice for giving the stereoscopic effect with lantern projectors is the following: A slotted disc is rapidly rotated before two lanterns, by which the views are projected on the screen in rapid alternation. The observer looks at the pictures through other slots cut on the rim of the disc in such manner that the right eye sees only the picture from the lantern on the right and the left eye that projected by the left lantern. By this device, it is said, if the rotation of the disc be made sufficiently rapid, the stereoscopic effect is produced without any perceptible flickering. W.

THE WATERHOUSE-FORBES METHOD OF AND APPARATUS FOR STERILIZING AND HEATING LIQUIDS.

[*Being the report of the Franklin Institute, through its Committee on Science and the Arts, on the invention of Addison G. Waterhouse and John S. Forbes. Sub-Committee: A. C. Abbott, Chairman; H. W. Spangler, H. R. Heyl, Philip Pistor, H. F. Keller.*]

HALL OF THE FRANKLIN INSTITUTE,
[No. 2171.] PHILADELPHIA, March 6, 1901.

The Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts, acting through its Committee on Science and the Arts, investigating the merits of the Waterhouse-Forbes Method of and Apparatus for Sterilizing and Heating Fluids to Predetermined Temperatures, reports as follows:

The investigating committee has subjected the Waterhouse-Forbes method and apparatus for the sterilization of fluids to what it deems the necessary investigation and tests, and begs leave to submit the following report:

Letters patent for the apparatus were granted to Addison G. Waterhouse and John S. Forbes, on November 28, 1899 (No. 638,192), and again on August 7, 1900 (No. 655,665).

An examination of the apparatus shows it to consist of a metal chamber divided into two compartments by a deeply corrugated partition. Into the one of these chambers the fluid to be sterilized is allowed to flow until a certain fixed level is reached, when its further passage is impeded. At this point provision is made for heating to the boiling point or any other desired lower temperature a small volume of the fluid. By such heating ebullition results, and this, together with the necessary expansion in volume, carries the fluid over a weir into the other compartment of the apparatus at a temperature at or about its boiling point. As it passes by gravity into the second compartment, and flows over the deeply corrugated or fluted partition that separates it completely from the inflowing, unheated fluid,

its temperature is gradually reduced until it reaches the point of exit where it leaves the apparatus at a temperature of from 4 to 5° higher than that which it had on entering.

The important features of the apparatus are that it can operate successfully only through the agency of sufficient heat to cause the fluid to boil over the point at which the continuity of its flow is purposely broken, thereby certainly destroying the vitality of those disease-producing organisms

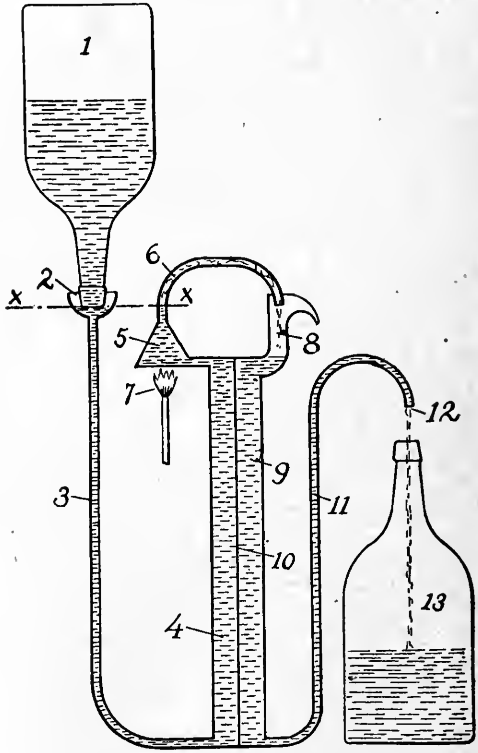

FIG. 8.

that are concerned in the causation of the common water-borne diseases, and that by the withdrawal of heat, the complete stoppage of the flow of water through the machine is brought about, thus preventing all possible contamination of the sterilized water by the inflowing unsterilized water. The principles involved and the mode of

operation of the apparatus are best understood by the accompanying diagram and more or less detailed description.

Fig. 1 is a purely diagramatic view of the ærostatic feed apparatus, and serves to explain the method of operation.

The raw or unsterilized water is supplied from the inverted bottle 1. The water runs from the bottle 1 into the cup 2, then down through the pipe 3 into the compartment 4 of the heat exchange, which it fills. When compartment 4 is filled, the water runs into the heater 5 and rises in the pipe 6 to the level *X*, where it stops. No more water will now run out of the bottle 1, because its mouth is sealed by the water in the cup 2 at the level *X*. The burner 7 is now lighted and heat is applied under the heater 5, which causes the water in the heater to boil, and in boiling it rises in the pipe 6 and flows over into cup 8, just as a pot on a cooking range will boil over. It is therefore impossible for any water to pass through the apparatus until it has boiled, for it is only by boiling that it can rise sufficiently in the pipe 6 to flow over into the cup 8. This boiling lasts for but the fraction of a second, and once the water has passed through the pipe 6 it is removed from where heat can again reach it. When some water has boiled over, as above stated, the level of the water in the heater 5 and likewise the level of that in the cup 2 is lowered. This exposes the mouth of the bottle 1, so that a small quantity of air enters the bottle and allows a corresponding quantity of water to run out of the bottle and refill the cup 2 and heater 5 up to the level *X* again, when the mouth of the bottle is again sealed by the water, and no more water can run out of it until the level is again lowered by reason of more water boiling over through the pipe 6.

This action becomes continuous, for the flame 7 is constantly boiling the water in the heater 5 and causing it to flow over through the pipe 6. The water continues to boil over into the cup 8 and quickly fills compartment 9 of the heat exchange. When compartment 9 is filled the water runs out of the pipe 11 at the opening 12 into the receiving

bottle 13. While passing down through the compartment 9 the heat of the water, which is boiling hot, is transferred, by conduction, through the thin metal partition or diaphragm 10 to the cold water passing up through compartment 4, so that the water which is boiled in the heater 5 passes out of the apparatus nearly as cold as that entering, while the cold water entering the apparatus becomes heated as it passes up through compartment 4, and reaches the heater 5 in a very hot condition and nearly at the boiling point.

Therefore, the only heat which has to be supplied to keep the apparatus running continuously, is that necessary to bring the already highly heated water entering the heater 5 to the boiling point, and cause it to rise above the normal water level X and boil over through the pipe 6, and so pass on through the remainder of the apparatus to the discharge outlet 12.

The committee has subjected the apparatus to such tests as it deemed necessary to determine its sanitary value as a sterilizer of purposely contaminated waters. As a result of these tests it was found that if water be purposely impregnated with very large numbers of living, non-spore bearing bacteria of known species, and then passed through the apparatus, these bacteria are all killed during the passage and the water leaves the apparatus sterile in so far as the species of bacteria used are concerned. Since it is in the non-spore forming group that the pathogenic species commonly carried by polluted waters belong, the sanitary importance of the apparatus is at once manifest.

When the more resistant spore-bearing varieties of bacteria were substituted, the results of this method of sterilization, though not so uniform as with the less resistant forms, were, however, sufficiently satisfactory to warrant the opinion that for all practical purposes the outflowing water was sterile.

The advantages of the apparatus may be briefly summarized as follows:

(1) In order for it to operate, all water passing through it must be brought to the boiling point.

(2) The time of boiling and the rapidity of cooling are so brief as to rob the water of but a part of its naturally contained gases.

(3) Living bacteria that are concerned in the causation of water-borne diseases are destroyed in passing through the apparatus.

(4) The action of the apparatus is automatic and it may be kept in continuous operation so long as the supply of raw water and a sufficient source of heat are available.

An objection that has been raised against the apparatus is that it does not clarify the water. This is true, but is of importance from the æsthetic standpoint only, and is moreover a defect that is easily remedied and one that in no wise lessens the sanitary value of the apparatus.

In view of the ingenuity displayed in the adaptation of fundamental physical principles; the fact that the apparatus as perfected is unique; that it is of extreme simplicity and with ordinary use is not liable to be disordered; and finally, its manifest sanitary value, the Franklin Institute awards to the inventors, Addison G. Waterhouse and John S. Forbes, of Philadelphia, Pa. the Elliott Cresson medal.

In reaching its conclusions, the committee has not only personally inspected the apparatus and subjected it to tests under its own supervision, but has also taken into account the elaborate report made upon the apparatus by the surgeon-general of the United States Army.

Adopted at the stated meeting of the Committee on Science and the Arts, held Wednesday, May 1, 1901.

JOHN BIRKINBINE, *President.*
WM. H. WAHL, *Secretary.*

Countersigned by

LOUIS E. LEVY,
Chairman Committee on Science and the Arts.

CHARLES E. SMITH.

HIS RELATION TO THE AMERICAN IRON INDUSTRY.

BY E. ALEX. SCOTT.

The Franklin Institute, in its three-quarters of a century of active life, has numbered among its members many men whose names will remain inseparable from some of the most important inventions and discoveries of the nineteenth century. We, their successors, are proud of their achievements; but, in these later days of technical schools and industrial progress, we can have little conception of the difficulties under which they labored in working out the problems which they solved. Nor do we duly appreciate the tremendous influence which the Institute has exerted through all the period of its existence, during a large portion of which it was the chief, and almost the only source of technical information. How great that influence has been can never be known.

Among those who have attained to eminence in particular industries or public station many were, in early life, constant attendants at the meetings of the Institute and drew inspiration from the bright intellects whose recorded thought is now a priceless heritage. Although they did not become prominent in the work of the Institute, they went into the world equipped with the knowledge which brought them fame and fortune.

Among these, the late Charles E. Smith, President of the Philadelphia & Reading Railroad Company, was a notable example. Mr. Smith is best known to the older members of the Institute and to the public generally as the capable engineer and financier under whose brilliant management

the Reading Railroad, a defaulting corporation, was brought up to a state of physicial efficiency and financial prosperity until then unexampled in the history of railroading. The golden age of that great property is spanned by the period of his presidency. His career as president, from 1861 to 1869, stamped him as a railroad manager of the first rank, a far-seeing financier of unflinching integrity, and as a patriot who fearlessly supported his government in the most critical period of its existence, with the very essential aid of the property under his control, while the most powerful interests conspired to defeat his purpose.

Few of the members, however, knew what Mr. Smith's relations were to the infant iron industry of this country, which has grown to such proportions that it has outranked every other, and has made America the first among nations. The history of the marvellous progress of metallurgical science can be read in the recorded transactions of the Institute, but it is fitting that a chapter should be added to show how the scattered energies and diverse methods of the early American workers in the art of iron manufacture were organized in the interest of scientific and financial success.

Born in Philadelphia on November 1, 1820, educated at West Town School and brought up in the principles and faith of the strictest sect of the Society of Friends, Charles E. Smith commenced the practical work of his life at the age of eighteen years as a member of an engineering corps, engaged in the laying out and construction of a railroad in Tioga County, Pa. When it was completed he was appointed Superintendent, and also had supervision over the Blossburg Coal Mines, whose product the road was built to transport. Thus, right at the beginning of his business career, he was called upon to assume the duties of administration, as well as the technical work of a civil and mining engineer. The six years spent in that region were valuable in experience. There he formed that habit of quick decision and prompt execution which characterized all his later business career. His orders were imperative and permitted neither of modification nor delay in their execution. This was the natural outcome of supreme authority en-

trusted to one so young, and his appointment at that age was an evidence of the recognition of his ability by those who placed him in that position.

He returned to Philadelphia in 1844 to seek a wider field for his energies. He had seen enough of the natural resources of the State to convince him that the iron industry must become an important one. Bar iron, rods and rails were then nearly all imported, and the transportation facilities were very meagre. After studying the subject for a year or two, he designed, and in 1846 built, the Fairmount Rolling Mill, whose site on the Schuylkill River above Fairmount Avenue, at the foot of Lemon Hill, is now occupied by the Lincoln Monument. The Reading Railroad on one side and the boats of the Schuylkill Navigation Company on the other gave ample facilities for the transportation of materials and products.

Mr. Smith's connection with the manufacture of iron extended over a period of about sixteen years, from 1845 to 1861, during the greater portion of which he managed his own plant. Among his contemporaries and associates during that period were Abram S. Hewitt, John Fritz, Coleman Sellers, James Moore and Washington L. Jones, to all of whom the writer is indebted for information as to Mr. Smith's enterprise and ability, and to the condition of the iron industry at that time.

Nearly every branch of the business was then in its formative stage. The processes for the reduction of the ores, the carbonization of the iron and manufacturing it into merchantable shapes were but crude imitations of foreign methods. Experience with American ores and fuels had not been sufficient to develop the character of the one or the value of the other, and American genius had not then set its stamp upon any of the improved machinery which has since become such an important factor in the economy of production. These gentlemen unite in saying that Mr. Smith was a remarkably energetic and progressive man, and was quick to recognize the value of any real improvement and adopt it in his business. Some of these improvements were first put to use in the works under his management.

The Fairmount mill was hardly in operation before he began to make improvements in it. The late James Moore, who was called in to make some changes in the rolls, said these improvements were radical, and were great advances in the art at that time. Among these was an arrangement to use the fire from the puddling furnaces to heat the water under the steam boilers, saving not only a great deal of coal which cost more then than now, but also the handling of it. The changes in the rolls were to ensure the rolling of rods and bars true to size. It is said that the Fairmount mill was the first in this country to roll rods that the locomotive builders would be satisfied with. More than a decade after this the number of mills in the country that could roll round or square iron true could be counted on the fingers of one hand.

In those days nearly all the rolling mills had puddling furnaces and prepared their own iron for the rolls. There was little knowledge of the character of the cast iron bought from various furnaces, and only an empirical knowledge of how to prepare it for the rolls.

The best practice was to depend upon the judgment of a foreign skilled laborer. The steam hammers of the period were lifted by a cam and descended by their own weight. The Nasmyth steam hammer had, in 1846, just been brought to notice in this country through the late Samuel Vaughn Merrick, and Mr. Smith was one of the first to appreciate its value and put it to use in his mill. In this he was opposed by his partners, but his will was law, and the hammer went in with excellent results.

The mill had been running less than a year when Congress repealed the Protective Tariff Act of 1842. Mr. Smith's opinion in favor of the protection of American industries had been formed while in charge of the Blossburg Coal Mines, which had been started into activity and made prosperous by the passage of the Act. Recalling the general business stagnation, and the idleness in mine and workshop which preceded its enactment, he prophesied disaster to the iron mills by its repeal, and at once sold out his interest to his partners, who were not of his mind. It

is a matter of record that more than two thirds of the furnaces of the country were shut down within the next two years, and among them the Fairmount Rolling Mill.

For the next few years he was content to take charge of the property of other ironmasters and risk none of his limited capital. For two years he was Manager of the Renssalaer Iron Works, Troy, N. Y., which was the first rolling mill in the Empire State to make rails. It was a comparatively new industry in this country. Rails had been rolled at Mt. Savage, Md., in 1844, and the first T rails at Danville, Pa., in the same year. Cooper, Hewitt & Co., who built, and still operate, the Trenton Iron Works, rolled T rails in 1846.

They were the first in the world to make heavy rails, and rolled them up to 90 pounds per yard at that early period. One of these rails, made in 1846, was taken out of the track of the Camden & Amboy Railroad in 1898, after more than fifty years of service. Robert L. Stevens, President of the Camden & Amboy R. R. Co., put foreign made T rails into that road in 1836.

To the form, weight and stiffness of rails Mr. Smith gave much study and made some important changes in the rolls for rail making while at Troy. He became convinced, however, that the iron business could not be made successful at that place under the existing conditions, and severed his connection with the works.

Soon after, he went to Europe, partly to study the methods of manufacture and conditions of success in the various iron centers, and partly to determine whether Europe or America offered the greater advantages to a young man with limited capital. Going there well recommended, he was given abundant opportunities for collecting facts in relation to the iron business, which, with the experience he had already gained, gave him a comprehensive grasp of the whole subject. More than a year was spent in this study, and he pursued his inquiry with that zeal and careful attention to details which characterized his entire life.

He returned convinced that America offered the best

field for a young man's energies, and well equipped to meet the untoward conditions which surrounded the American iron manufacturer. He recognized the fact that, with a difference of nearly eight dollars a ton in labor cost in favor of Scotch pig iron, and a much greater difference in the labor cost of a ton of rails, the industry could not thrive in America without the fostering care of the general government. To secure that protection he bent all his energies, and on every occasion presented the data he had secured to show what might be done in the development of iron manufacture under proper conditions.

Soon after his return from Europe he became manager for Reeves, Buck & Co., in their rolling mill at Phoenixville. In the following December (1849) a convention of "Manufacturers and Dealers in Iron" was held in Philadelphia to take measures to relieve the depression of the iron interest by enforcing upon Congress the necessity for revising the tariff. The summer preceding this meeting had seen much agitation of this subject, and the names first affixed to the call for the convention were those of his employers, Reeves, Buck & Co., who were in full sympathy with the views of their manager.

Of this meeting Charles E. Smith and Nathan Rowland were secretaries. A committee on the State of the Trade and Statistics was appointed, of which Mr. Smith was chairman, and Stephen Colwell, was chairman of the committee on a Memorial to Congress. The reports of these two committees are marvels of clearness, not only in the marshalling of the facts presented but in their diction. They form an epitome of the knowledge of the iron industry of the period on both continents, and are a fitting beginning of the literature of the industry which has made America the arbiter of the world's destinies.

To Mr. Smith is due the credit of gathering and compiling these statistics with great judgment and consummate skill. He was quite willing to undertake the task of collecting the data from the scattered American manufacturers, but he had little conception of the labor and hardship which he afterward experienced in his quest for this information.

As shown in his report, he visited forty-five counties of Pennsylvania in which there were iron works, and obtained at first hand the statistics of their capacity, product and character of work turned out. When it is considered that there were but few miles of railroad in operation at that time, and that a large proportion of the forges and furnaces were inaccessible by stage lines and had but a local custom, and that only by diligent inquiry could they be located, the thoroughness with which this canvass was made, and the unquestioned accuracy of the report, must be regarded as little less than marvellous. Traversing the state three times from east to west and four times from north to south, by rail, by stage, by country wagons, on horseback and even on foot over mountains and through the wilderness, although the winter was one of the coldest of the century, he traveled over 2,500 miles and visited 504 charcoal furnaces, forges and rolling mills. The Convention had no funds. Starting with ten dollars of his own money he begged his way, paid his expenses and returned in the Spring with three hundred dollars in his pocket.

The report was made to Congress and was printed. The figures presented were drawn upon largely by the protectionist newspapers throughout the country. The Convention was chiefly useful to the iron manufacturers by bringing them to know each other and leading them to unite for the furtherance of their mutual interests. One of its most important fruits was the organization of the American Iron Association in 1855, of which Mr. Smith was elected treasurer and J. P. Lesley secretary. The Association undertook the compilation of a statistical guide to the iron works of the United States, the facts obtained being published in the Bulletin of the Association. These facts were, in 1859, presented in one large volume entitled the "Iron Manufacturer's Guide."

Of this volume, Mr. James M. Swank, the Vice-President of the American Iron and Steel Association, says: "In all this hard work Mr. Smith was the active and efficient assistant of Professor Lesley; in fact he may be said to have had from first to last, a leading share in the compilation of

the statistics gathered by the Association from 1855 to 1859. Because of this connection, and his previous work in collecting information of the iron industry of Pennsylvania in 1849, Mr. Smith was unquestionably entitled in his lifetime to the honor of being regarded as the first statistician of the American iron trade."

After lying idle for several years, the Fairmount Rolling Mill was re-purchased by Mr. Smith at sheriff's sale, and, under the name of Charles E. Smith & Co., he rehabilitated it, put in rolls for making railroad iron and also made skelp for his silent partners, Morris, Tasker & Co. He did not resume the manufacture of merchant bar, which was abandoned as unprofitable. The rails were principally light mine rails, not exceeding 50 pounds per yard. The very latest improvements were introduced and Mr. Coleman Sellers, who formed Mr. Smith's acquaintance about this time, said that William Sellers & Co. made for the mill a hot saw to cut the rails. It was one of the first to be put in use. Mr. Sellers said Mr. Smith showed much mechanical ability and seemed bent on doing the best possible with the plant, putting in not only the most efficient rolling machinery, but also other machinery to work the rails to completion.

The mill was equipped with puddle furnaces. As far back as 1846, when it was first built, the iron was boiled. Pig-iron, as it could be bought from the furnaces, was melted in deep furnaces. The molten iron was stirred, and iron scale (oxide of iron) from the mill was thrown into it; so that the output from the furnace of a good boiler would be greater than the weight of pig-iron put in. The skill of the furnaceman was best shown in his ability to collect the wrought iron in small balls, raise the heat so as to weld several of these balls into one, dip the ball out of the furnace, tilt the mass so as to let the slag run out, and do this so skilfully that the phosphorus would not be taken back into the iron. The ball was then taken to the squeezer or hammer.

About this time an automatic puddler was invented by Mr. William Sellers, but before it came into practical use the

Bessemer process was brought out, which, being a cheaper one, did away with puddling furnaces to a greater or less extent.

Improvements in the quality of the iron had been studied by Mr. Smith in an empirical way with fairly good results. The quality of the skelp made for Morris, Tasker & Co. was a matter of vital importance in the manufacture of tubes, and extraordinary efforts were made to hold their custom. They had put their money into the new venture, hoping the mill would turn out a product equal to that which they had hitherto imported. Some quite spirited discussions are said to have occurred between Mr. Smith and Mr. Thomas Tasker, the elder, in regard to the quality of the iron.

Mr. Washington Jones, of the Institute, who was a contemporary of Mr. Smith's, has a good recollection of the mills of that period. Reany, Neafie & Co., with whose establishment he was then connected, used to order iron from the Fairmount Rolling Mill. There was then but one other rolling mill near Philadelphia, that of Nathan Rowland & Co., and merchant bar only was made there. Mr. Jones made many alterations and repairs in Mr. Smith's mill while with Reany, Neafie & Co., and that firm built a 150 horse power engine for it in 1846, the first stationary engine they had ever built. The rail mill and rod mill were made by James C. Moore, the founder of the Bush Hill Iron Works. The latter rolled from $\frac{3}{16}$ to $\frac{5}{8}$ inches in diameter. Three-quarter and 1-inch rods were rolled by hand. It then cost $6.50 a day for the man who run the mill, and he spent about half that time at the "Nanny Goat Tavern" on top of the hill. Truly the conditions of success in iron manufacturing were lacking at that period.

Up to the time when Mr. Smith was called to the Presidency of the Philadelphia & Reading Railroad Company in 1861, he continued to manage the Fairmount Rolling Mill, an increasing proportion of its product going to the pipe works of Morris, Tasker & Co. After disposing of his interest in the mill it was run by Charles Wheeler, one of the members of that firm.

His selection as president of the Reading was a surprise to many, but his fitness for the position was well understood by those who made the selection. In 1852 he was elected to the Board of the Schuylkill Navigation Company, and for several years was an active member of that Board. The railroad was its competitor, and the questions constantly coming up for settlement between the two familiarized him not only with the advantages possessed by each, but convinced him of the desirability of uniting the two under one management. He was essentially a railroad man, his education and experience teaching him that the canals had had their day. Under his management the union was effected, and as the canals could not be improved without necessitating the rebuilding of both canal and floating equipment, they rapidly went out of use.

The history of the Reading Road under Mr. Smith's management has no parallel in respect to improvement in physical condition, development of natural resources along its lines, discipline of organization and successful financial results. He had spent all his life in the dual position of mechanical engineer and manager, putting his own conceptions into effect and profiting by the results. He made the track a fit highway for heavy traffic, adjusted the burden to every struggling industry on his lines, and faithfully turned into the company's treasury every dollar earned by its heavily laden trains. That he should have broken down in health after eight years of such labor is not surprising. His brilliant achievements while President of the Philadelphia & Reading Railroad are better remembered after the lapse of a third of a century than his earlier work in the development of the iron industry. The former is still a brilliant memory; the latter looks insignificant when comparison is made with the little rolling mill on the Schuylkill and its antiquated methods; but when the movement to organize the iron interests, in which he was the principal factor, is considered, together with the results which flowed from it, it may fairly be questioned whether that work ought not to be regarded as being the more important one.

JOHN LUCAS.

The subject of this sketch, who was one of Philadelphia's leading manufacturers, and prominently identified with the Franklin Institute and many other public institutions of the city, was born at Stone, Staffordshire, England, in 1823.

His early education was directed with the view of fitting him for commercial life. He appears to have early exhibited a preference for chemical studies, in which he became proficient, and thus laid the foundation for that successful

career as a manufacturer of paints and colors, on which he subsequently entered.

In 1844 Mr. Lucas came to America, and, after some time spent in Canada and other parts of the Western Continent, he finally settled in Philadelphia, in 1849, and shortly thereafter became a citizen of the United States.

He began his business career in this country as a foreign commission and shipping merchant representing several large European houses.

Mr. Lucas first began the manufacture of paints and

colors at No. 33 North Front Street, and, the venture proving successful, shortly afterwards removed to a larger building on Fourth Street, between Race and Arch Streets. His early acquired knowledge of chemistry greatly aided him in the development of this business, and the results of his continued technical study appeared in several letters-patent for improvements in the manufacture of paints and colors.

In 1852 he took Joseph Foster into partnership, and removed to 130 Arch Street. About this time he purchased a large tract of land in Camden County, N. J., which was noted for having a sheet of remarkably pure water upon it, which was of great use to him in producing superior colors. There he erected the since famous "Gibsboro Paint and Color Works" among the most extensive in the country.

His energy, business acumen and technical skill made it possible for him to utilize the natural advantages afforded by this favorable location to the best advantage, and the products of the house soon enjoyed a high reputation, and came widely into use.

In 1857 John Lucas was joined by his brother, William H. Lucas, and the establishment bearing his name at 141 and 143 North Fourth Street, is one of the largest and most important of its class in the United States.

Mr. Lucas was one of the pioneers in the development of Atlantic City, serving first as a director and then as the President of the Camden & Atlantic Railroad Company. He was an active member of the Society of the Sons of St. George, and for several years its president. He was warmly interested in the Hayes Mechanics' Home.

He was elected a member of the Franklin Institute in 1884, and for years was a frequent attendant at its meetings, in which he exhibited a lively interest. He was elected to the Board of Managers in 1889, and served until 1895, when his growing physical infirmities compelled him to decline further service.

He married, in 1854, Harriet Annie Boun, of Philadelphia, daughter of Abraham and Ellen Boun, of , England. The fruits of this marriage were nine sons and six daughters. He is survived by twelve children.

Mr. Lucas was a man of most generous and humane impulses, genial in manner and of the most amiable and sympathetic disposition. His associates in the Franklin Institute sincerely mourn his loss.

WALDRON SHAPLEIGH.

Waldron Shapleigh, Chief Chemist to the Welsbach Company, and an esteemed member of the Franklin Institute, died on August 30, 1901, at his summer home in West Lebanon, Me.

Mr. Shapleigh was the son of the late Marshall Spring Shapleigh, and was born in Philadelphia in 1848. At an

early age he confined his education to the study of chemistry under the late Prof. J. P. Williams. At the age of 19 he was appointed as chemist to the Blair County Zinc Works in Pennsylvania, and a year later entered the Lehigh University as instructor of chemistry under the late Prof. Chas. M. Wetherill, whose place he temporarily filled upon his death. While at Lehigh University his interest was directed to the beet sugar industry, which was at that time engaging the attention of the scientific world. He resigned his position and went to France where he remained for two years so as to gain an intimate knowledge of this industry.

Upon his return to America he was engaged as chemist to the Kings County Sugar Refining Company, of New York, in whose employ he remained until the dissolution of the company, at the time of the formation of the American Sugar Refining Company. Shortly thereafter he accepted the position of chief chemist with the Welsbach Company, which company he served with great distinction until his death.

Mr. Shapleigh's connection with the Welsbach Company dated from the beginning of the industry in America, and it was during this period that he gained a wide reputation in scientific circles both in Europe and America, as the leading authority on the properties of the rare earths. His exhibitions of rare earths were recognized by the highest awards at all of the exhibitions in America and Europe.

During the Columbian Exposition held in Chicago, Ill., in 1893, Mr. Shapleigh acted as one of the judges of award in the Section of Chemistry.

He was a member of many scientific organizations, among which were the Chemical Society of London, Society of Chemical Industry, and Society of Arts of London; also of the American Chemical Society and the Franklin Institute.

Mr. Shapleigh was a man of unusual character, possessing a rare combination of strength and gentleness. All who knew him deeply loved and respected him, and have sustained a severe loss in his death.

He leaves a widow, a son and daughter.

NOTES AND COMMENTS.

USE OF KITES IN METEOROLOGICAL WORK.

London *Nature* has the following item of interest in reference to the latest developments at the Blue Hill Observatory, Mass., with the use of kites in meteorological investigations:

Until recently, no flights were made in winds having rates of less than twelve miles an hour; but Mr. A. L. Rotch, the Director of the Observatory, has now used the common method of creating an artificial wind and raising kites in comparatively calm weather by motion of the earth-end of the kite string or wire, the motion in this case being obtained from a rapidly moving

tug. The apparatus employed consisted of a portable windlass containing 3,600 feet of wire, three Hargrave kites having a total lifting surface of 80 square feet, and an instrument for recording temperature, pressure and wind velocity and humidity. This outfit was installed on the upper deck of a tug in Massachusetts Bay, on August 22d. Two flights were made and the greatest heights reached were 2,630 and 2,670 feet. With more wire and kites much greater heights could have been obtained. The natural wind varied between six and eleven miles an hour, and was much too light to elevate the kites and apparatus, but by steaming against the wind the velocity relative to the tug and kites was increased to between fourteen and nineteen miles an hour. In this artificial wind the kites rose easily, and so steadily that they could be let out from and hauled into hand without the slightest risk to kites or instruments. The kites were very sensitive to alterations of the course of the tug, and began to fall whenever the course varied 30° to 50° on either side of the mean direction of the wind. The experiment shows that meteorological records at great heights may easily be obtained during calms or very light winds by means of kites flown from a rapidly moving steamer; and that it is now possible for the observer and student to work uninterruptedly under almost all conditions of wind and weather.

LINEN MANUFACTURE IN THE UNITED STATES.

At a recent convention of the New England Cotton Manufacturers' Association the address of one of its members contained the recommendation that the manufacturers of that section of the country might find it profitable to turn their attention from cotton to flax. It is somewhat remarkable that, although the textile industries in this country have been very largely developed, especially within recent years, the linen manufacture seems to have had little share in this growth, and still remains practically in its infancy.

For this there are good reasons. Down to the period when the cotton manufacture by the factory system gained a foothold, the raising of flax for spinning and weaving was a widespread domestic industry, and nearly every household raised enough for its own needs. With the advent of cheap cotton goods the spinning wheel was relegated to the attic, the growing of flax for the household wearing apparel was abandoned, and the general knowledge of the process of treating the fibre became one of the lost arts.

At the present time the several large linen mills in this country are compelled to depend largely for their supply of raw material on imported flax.

The importation of linen goods into the United States represents an enormous sum annually, and it would seem the course of wisdom for the State and National legislatures to take suitable measure to encourage the establishment of the flax industry as a desirable domestic manufacture, as has been done with other branches of industry—notably the manufacture of tin plates —and with most satisfactory results.

In one respect the flax industry bears a resemblance to the sugar beet industry, namely, in that it requires for its successful introduction the active and intelligent co-operation of the farming community; but this difficulty has been readily overcome in the one case, and doubtless would not prove to be serious in the other. A large amount of flax is raised, especially in the West-

ern States, for seed from which the oil is extracted, so that the crop is one with which the farmers generally are familiar, but for the manufacture of fibre the flax must not be allowed to ripen its seed, but must be pulled up by the hand while green. The fibre of the ripe flax is found to be too coarse and harsh for producing fine linen, and the process of threshing out the seed breaks and tangles it so much as to make it unfit for anything but tow and paper stock. For the linen manufacture, therefore, the flax must be grown specially, the fibre must be specially treated, as will be described below, and the seed cannot figure in the crop.

A well-known and highly capable mill engineer, Mr. Samuel Webber, of Charlestown, N. H., and who has been prominently identified with the New England cotton manufacturing industry for years, has given in the *Boston Journal of Commerce* some interesting experiences bearing on the linen industry in the United States, which are so apropos to the subject of this article that they are quoted in part in what follows:

"It is in no way a difficult matter," says Mr. Webber, "to introduce the linen manufacture into New England so far as the mechanical operations are concerned; the only trouble will be in getting a proper supply of the raw material in suitable condition to be spun."

In 1880 Mr. Webber made a careful study of the linen manufacture in England, Scotland and Belgium to determine the question of the practicability of introducing the industry into this country. He thought then that the great objection would be the large amount of manual labor required to prepare the fibre for the mill. The treatment it must receive is thus described:

"Flax for spinning is not allowed to ripen its seed, but is pulled up by hand while green, and the stalks kept in bundles as pulled, are rotted, or 'retted' in shallow ponds or streams, being frequently carefully turned until the bark and woody parts of the stalk are so far decayed as to be readily broken and separated from the fibre when dry. This is done by a sort of wooden blade or sword, and is known as 'scutching.' The next step is 'hackling' or drawing the fibres through a set of steel combs, which take out the chips of bark and wood, and the fibre is then in bundles ready for the market. The operation of retting requires a good deal of wet and dirty manual labor. * * *

"There is no trouble in growing the flax. One of my earliest recollections, more than sixty years ago, is of linen clothes for summer made of flax grown, hackled, spun and woven by hand in this, my native village, and there then stood the remains of an old dam, or a brook, near the village known as the 'Oil Mill Dam,' where a previous generation had crushed the seed for the oil. * * *

"Wherever it (flax) is raised for manufacturing purposes great care is taken to keep the fibres smooth and parallel from the start all the way through, and the long bundles of fibre of which each apparent fibre of stalk is composed are kept together until the last operation of spinning, when the roving is run through hot water to dissolve the vegetable gluten before going to the drawing rolls which then pull them apart and deliver the fine yarn."

Referring to the co-operation of the farmers in the production of the raw material for the mills, Mr. Webber concludes as follows: "What is wanted

first is the distribution of samples of properly prepared flax through the agricultural districts, with an offer to pay the price for it for which it can be imported and to ascertain if the farmers will agree to produce in proper condition which it cannot be if ripened for seed." W.

TIN MINING IN THE MALAY PENINSULA.

A special mining commission of the London *Economist* reports as follows:

The lower half of the Malay Peninsula consists of the states of Perak, Selangor, Pahang, Negri Sembilan and Johore. The first four are known as the Federated Malay States—which are under the protection of Great Britain—and Johore will probably enter the Federation sooner or later. To the north of these are numerous other Malay states, quite unexplored as yet. These are nominally under Siamese influence, and are closed to European exploitation. The Federated Malay States, especially Perak and Selangor, contain by far the largest and richest tin mining fields known, and as they supply at present about four-sevenths of the world's output of tin their importance from the mining point of view can be easily imagined. These great tin deposits stretch from the north, through the independent Malay states, into Siam and the province of Yunnan, in China, and south into Sumatra, Banca, Billiton and other of the Dutch Indies.

A rough estimate of the world's present yearly supply of tin may be stated as follows:

	Per Annum. Tons.
Federated Malay States	45,000
Independent Malay States, Siam and Yunnan	4,000
Dutch Indies	15,000
Australia and Tasmania	3,000
Bolivia and Peru	4,000
Cornwall	4,000
Total	75,000

The question naturally arises: Is the output of tin going to increase? Will not the present high price before long have the effect of bringing many more producers into the market?

But tin is a metal which, relatively to copper, lead, silver and gold, is found in few countries, and I am inclined to think that the output, except in the Malay Peninsula itself, will not increase to any appreciable extent. In the Federated Malay States I can see no sign of waning in production, and when they are worked out, many years hence, the at present unexplored states in the north of the peninsula will doubtless continue to supply the world.

In the Federated States many of the richest patches of the alluvial tin bearing wash have already been worked out; but the lower grade areas, which now, owing to the higher price for tin, are as highly profitable to work as the richer ones used to be, appear to be of almost unlimited extent.

Every here and there you come upon one of these mines. From out of the big shallow holes thousands of Chinese coolies pour, carrying on their heads baskets of the tin-bearing gravel, which they empty into the sluices

and as the endless stream passes and repasses, one's belief in the permanence of this industry is crystallized.

On every side, too, you see dense tropical forests. One glance will tell you that, as this land is cleared and prospected, thousands of acres of alluvial tin carrying areas will be exposed, the existence of which is not now known. But the Government is very wisely putting a stop to the habit of taking up only the richest areas. The poorer lands must be worked out first, especially with the present high price for tin, and in days to come the output can be regulated and the revenue assured.

Practically the whole of the tin areas are owned and worked by Chinese, and some of the wealthiest proprietors now estimate their fortunes in millions of dollars. Europeans have found, by costly experience, that the Chinese coolie, in tin mining, will give a fair day's work only to a Chinese master, and unless they can introduce hydraulic sluicing profitably their share in the tin mining industry will be an insignificant one.

COMPARATIVE MERITS OF THE FLAME AND ELECTRIC SAFETY LAMPS FOR MINERS.

Mr. H. W. Halboum discusses in a late number of the *Colliery Guardian*, the present status of the miners' safety lamp. Comparing the improved forms of flame safety lamps of the Davy pattern with the electric glow lamp, he advocates the former as being preferable. For this unexpected condition he adduces the following reasons :

The old form of miner's safety lamp was not devised for the purpose of enabling the miner to remain for any length of time with impunity in an explosive atmosphere. The flame of the lamp cannot pass through the gauze and ignite the explosive gas without, but the gas can penetrate within the lamp and burn within the flame chamber. There is where one of the most valuable properties of the Davy and similar lamps is exhibited. The enlargement of the flame by the burning of the entering gas from without gives the miner immediate warning that he has entered a dangerous working, and enables him to leave the dangerous neighborhood and report its condition.

The electric lamp, on the other hand, gives absolutely no indication of the presence of dangerous gases, being completely enclosed and independent of the surrounding atmosphere. It is free from the danger of igniting the mine gases as long as it remains intact, but if broken, is liable to ignite the mixture without warning.

For these reasons Mr. Halboum is an advocate of the most improved forms of the flame safety lamp, such as the Massant or the Maeselar lamp, believing them to be more desirable. To meet this objection brought forward by Halboum, the advocates of the electric lamp propose the use in addition to it, of a separate indicator for "fire damp" and "choke damp." This, in his judgment, entirely qualifies all the advantages claimed for the new lamp.

He summarizes his comments on the subject in the following argument : "Every practical pitman at the present day will admit that the ordinary type of safety lamp constitutes a safety lamp chiefly because it betrays the character of the outer atmosphere. If an explosive atmosphere is present, we do not want a lamp that will burn, and a man who will attempt to work in such

an atmosphere. We want a lamp that will give indications of the presence of such an atmosphere, and a man who is not insane enough to attempt to work in an atmosphere which is lately unfit for respiration." W.

BURNING BY BECQUEREL RAYS.

It has been recently announced in the *Comptes Rendus* that the invisible rays emitted by radium have an active effect upon the human skin. It is well known that X-rays, if sufficiently intense and in sufficiently long duration of action, exercise a destructive action upon the skin, which peels off and leaves an open sore that is slow to heal. Recently Walkoff and Giesel observed a similar action exerted by radium. Mr. H. Becquerel now describes the effects noted by him on his own person. He carried a few decigrams of radiferous radium-chloride, inside a small sealed tube, in his waistcoat pocket for a total length of time amounting to about six hours. In ten days a red mark, corresponding in position to the location of the tube, developed on his skin. It was followed by peeling and suppuration, and the sore did not heal for a month. This will add one more to the cheerful list of possible skin diseases that civilization enables us to classify, develop and diagnose. In addition to the ordinary sun-burning which is prevalent in the northern hemisphere about this time of year, and is sought by giddy girls or callow boys, we have arc light burns, X-ray burns and Becquerel-ray burns. It seems likely that the action in each of these cases is similar, but a careful comparative investigation into the differences of action would probably be both useful and interesting. While the sun burns at a distance of ninety-odd millions of miles, the arc light and Crookes tube act at a few centimeters, and radium at a few millimeters.—*Electrical World.*

BOOK NOTICES.

The Phonographic Manual. By Charles Morrell. 8vo., pp. 490. Chicago: The Morrell Ve. 1901.

The author describes an improved system of shorthand writing, the modifications for accepted methods being based on certain original observations made by him. W.

Methods of Chemical Analysis and Foundry Chemistry. By Frank L. Crobaugh, M.S. 12m., pp. 79. Cleveland, O., 1901. Published by the author. (Price, $1.50.)

This hand-book for the foundry chemist is divided into two parts. Part I is devoted to analytical methods and suggestions, and Part II treats of the application of chemistry to foundry methods. The analytical portion treats of standardizing, sampling, and detailed methods of analysis of iron, phosphorus, manganese, calcium, sulphur, carbon, silicon and silica, aluminum and alumina, and copper.

Part II deals with the varieties of pig iron, coke and coals, figuring mixtures, figuring silicon, figuring sulphur, formulæ for castings, annealing, influence of elements in cast iron and the relation of the chemist to the foundryman. W.

Leçons sus les Moteurs á gaz et a Pétrole Faites á la Faculté des Sciences de Bordeaux. Par L. Marchis, Professeur adjoint de Physique à la Faculté des Sciences de Bordeaux. Un volume in-16 de xl-175 pages, avec 19 figures; 1901. Librarie Cauthier-Villers, Paris 1901. (2 fr. 75c.)

The work here entitled is a concise treatise on the theory and practice of the modern gas and oil engine. The theoretical side of the problem involved in this type of heat engine is elaborately discussed. W.

Cotton and Cotton Oil: Cotton; cotton-seed oil mills; cattle feeding; fertilizers. Profusely illustrated with original drawings. By D. A. Tomkins. Large 8vo, pp. 481. Charlotte, N. C. Published by the author, 1901. (Price $7.50.)

This work is the fourth of a series dealing with cotton and the associated industries.

The book is in three parts. Part I is a full treatise on the planting, cultivating and harvesting of cotton, and also a full discussion of all the present and prospective methods of ginning and baling cotton. The various round bale systems are fully illustrated and described. Part II deals with the manufacture and refining of cotton oil, and with the uses and final disposition of all the products. Part III is called "Correlated Industries," under which are grouped the fattening of beef cattle and the maintenance of dairy cattle on cotton oil products, and the manufacture and use of fertilizers. The use of home fertilizers, and the manufacture of commercial fertilizers each have full share of attention.

The book is profusely illustrated and is furnished with a good analytical index. The mechanical execution of the book is excellent. W.

The Telephone System of the British Postoffice. A practical handbook. By T. E. Herbert, A.M.I.E.E., etc. Second edition, revised with additions—with 156 illustrations. 12mo, pp. vii + 218. London and New York: Whittaker & Co., 1901. (Price 3d. 6s.)

The telephone trunk lines of Great Britain have been acquired and are operated by the State in connection with the postal service. This work was originally prepared to meet the needs of the employes of the postoffice, but was afterwards elaborated in book form. In embraces a number of chapters introductory to the subject of telephony in general, viz., the principles involved in the transmission of speech; the Bell telephone; transmitters and receivers, etc. Then follow a number of chapters devoted to the installation and operative details of the system. The present edition contains a new chapter entitled "Recent Advances in Switchboard Design." W.

A System of Phonoscript and Phonotypy. By Charles Morrell. Fourth Edition, 12mo., pp. 108. Chicago: Phonic Institute. 1890.

The author describes and illustrates in this little volume a system of phonetic writing and printing which will doubtless prove useful and suggestive to those who were interested in the reform of English orthography. W.

How to Become a Good Mechanic. Intended as a practical guide to self-taught men, etc., etc. By John Phin. Second edition, rewritten and greatly enlarged. 12mo., pp. 68, paper. New York : Industrial Publishing Company, 1901. (Price, 25 cents.)

The purpose of this work, as explained by the author, is to give to students who are endeavoring to pursue a course of study without a teacher a series of suggestions and hints as to "what to study, how to begin, what difficulties will be met and how to overcome them —in a word, how to carry on such a course of self-instruction as will enable the young mechanic to rise from the bench to something higher." W.

Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, September 18, 1901.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, September 18, 1901.

Vice-President THEO. D. RAND in the chair.

Present, 84 members and visitors.

Additions to membership since last month, 9.

The gift was reported of a marble bust (with pedestal) of the late John Struthers, one time an active member of the Franklin Institute. The gift was accepted with the thanks of the Institute, and the Secretary was directed to make suitable acknowledgment to the giver, Mrs. Helen Struthers Dunn, of Philadelphia.

Mr. Wm. McDevitt, Inspector of the Philadelphia Board of Fire Underwriters, gave a series of illustrations designed to exhibit the causes of explosions at fires, especially where chemical substances, such as chlorates, nitrates, volatile oils, collodion, guncotton, etc,, are involved. The speaker drew largely upon his extensive experience with such explosions, and urged the importance of instructing workmen who handle dangerously inflammable or explosive substances in factories, etc., concerning their properties. The experiments made by Mr. McDevitt were striking and instructive. Discussed by Messrs. Fullerton, Goldschmidt and the author.

Then followed a series of informal communications on the Pan-American Exposition, which were profusely illustrated with the aid of lantern slides. The participants were Mr. Louis E. Levy, Dr. A. E. Kennelly, Prof. H. W. Spangler and Mr. Carl Hering.

Mr. Joseph Steinmetz exhibited a number of aluminium plates badly corroded by the action of sea waters. These had formed the hull plates of the American cup yacht *Defender*.

The exhibit demonstrated in the most effective way the unfitness of this metal for purposes where it is exposed to contact with salt water or to an atmosphere laden with such moisture.

Adjourned.

WM. H. WAHL,
Secretary.

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CLII, No. 5. 76TH YEAR. NOVEMBER, 1901

CHEMICAL SECTION.

Stated Meeting, held April 25, 1901.

SOME OF THE WORK OF W. SPRING, OF LIÈGE.

BY ROBERT H. BRADBURY,
Member of the Institute.

In reviewing the work of one man, the choice of subject-matter is determined entirely by the historical consideration. One encounters, therefore, the danger of becoming incoherent, of making sudden and violent transitions from one subject to another. In order to avoid this I will make no attempt to describe Spring's work completely, but will select those of his papers which deal with two special subjects, and not consider the others at all.

I.

Much of his later work is concerned with the color and transparency of liquids. He has shown that most so-called colorless liquids exhibit very distinct colors when light is made to pass through a sufficiently thick layer. Thus,

when water is examined in a tube 26 meters long, it is found to have a blue color, which can be closely imitated by a solution of $CuCl_2$ of proper concentration. This gives a simple answer to the old question as to the cause of the color of large bodies of water. It is the natural color of the water which makes its appearance, owing to the thickness of the layer examined. Suspended matter reflects equally light of all wave-lengths, and cannot, therefore, be instrumental in producing the blue color, as was at one time supposed. In agreement with this stands the fact that the color is most evident in waters free, or nearly free, from suspended substances.

It is interesting to notice that this faint blue tint appears to be dependent on the presence of oxygen in the substance. Liquid oxygen is distinctly blue; liquid ozone intensely so. In order to test this conclusion Spring undertook the difficult and dangerous operation of preparing large quantities of anhydrous hydrogen peroxide.* He found it to possess the same color as water, but in considerable greater intensity.

The same color appears in organic compounds containing hydroxyl. In this direction experimentation is rendered difficult by the fact that there are few compounds which can be obtained in the large quantities required without an almost prohibitory outlay. It seems that the natural color of the carbon chain is gold-yellow, and this color is seen in all liquid carbon compounds which do not contain hydroxyl. The presence of oxygen not as hydroxyl does not affect the color.† Thus acetone possesses the same yellow color as liquid hydrocarbons.

On the other hand, hydroxyl communicates to compounds containing it a blue color, and methyl or ethyl alcohol in a tube 26 meters long, is bluish green and more transparent than water.‡ As the carbon chain increases in length, the yellow triumphs over the blue of the hydroxyl group. Amyl

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* *Zeit. Anorgan. Chem.*, Vol. 8, p. 424.

† *Bull. Acad. Belg.*, Third Series, 31, p. 246.

‡ *Bull. Acad. Belg.*, Third, Series 33, p. 165.

alcohol is yellowish-green. Another interesting point is the behavior of mixtures of miscible liquids. Each affects light passing through it as though it existed alone. The color produced by passing light through a mixture of two liquids A and B is exactly the same as that obtained when the light is caused to pass through a tube of A and then another of B placed end to end. Solutions of $LiCl$, KCl, KNO_3, $MgCl_2$, $CaCl_2$, $SrCl_2$, $BaCl_2$ possess the same color as water, but are less transparent. The amount of light stopped by a layer 26 meters in thickness increases with the concentration of the solution, but not proportionally.*

When a ray of light enters a dark room, through a chink in the shutter, the path of the light is visible. Every one is aware that this is due to the suspended matter of the air, and it is a familiar lecture experiment due, I believe, to Tyndall—to enclose some air over night in a glass box, the bottom of which has been smeared with glycerine. This catches the suspended matter and the track of a beam becomes perfectly invisible. Other gases behave in the same way when the suspended matter has been removed. Gases are said to be *optically empty* (optisch leer).

Now when a converging beam of electric light is passed into a liquid in a dark room the track of the light is brilliantly visible. There has been much discussion as to whether this effect is due to suspended matter, or to a peculiar property of liquid molecules of reflecting light sidewise. Spring settled this question by preparing water free from suspended matter. This cannot be done by distillation nor by filtration. Distillation of hydrant-water greatly increased the turbidity and filtration through raw cotton—which, when properly carried out, completely frees a gas from suspended matter—makes water more turbid than before. But when a suspension of silicic acid in water is placed in a U-tube and subjected to the influence of an electric current, the suspended particles proceed to the cathode, and the liquid about the anode becomes *optically empty*.† The path of a beam of light is just as invisible

* *Chemiker Zeitung*, Vol. 33, p. 375.

† *Bull. Acad. Belg.*, Third Series, 37, p. 174.

as in dust-free air. It is also possible to obtain optically empty water by purely chemical methods. Thus when ferric hydroxide or aluminium hydroxide is precipitated in water solution it catches and carries down the suspended particles and the liquid over the precipitate becomes optically empty. Crystalline precipitates like CaC_2O_4 or $BaSO_4$ have no effect. In preparing optically empty water, the air must be absolutely excluded, for a moment's air contact will charge the liquid richly with suspended matter.

So far it has been impossible to obtain an organic liquid in optically clear condition. Spring believes that the visibility of a beam of light in most liquids is due to the action of the liquid molecules upon the light, and not to suspended matter, but this point requires further investigation.

In *colloidal solutions* like those of the alkaline silicates, gum arabic, dextrine and gelatine in water, and alcoholic solutions of rosin, sandarach, and other resins, the path of the beam is always distinctly visible. This is another support for the modern conception which regards such "solutions" as simply suspensions of great fineness.

Salt solutions can be divided into two classes. Those of the alkalies and the alkaline earths, for instance, can be obtained optically clear just as readily as water itself. In those of Al, Cr, Fe, Cu and others the track of the beam remains obstinately visible. Hydrolysis—the reaction of the dissolved salt with water—supplies the explanation of this fact. When $Al\,Cl_3$ is dissolved in water the liquid is acid to litmus, inverts sugar and shows every evidence of the presence of hydrogen ions. Hydrochloric acid and $Al(OH)_3$ have been produced thus

$$Al\,Cl_3 + 3\,H_2O = Al\,(OH)_3 + 3\,HCl.$$

The $Al\,(OH)_3$ is colloidally dissolved and is responsible for the visibility of the light.

On the other hand, the hydroxides of the alkalies and alkaline earths are strong bases, there is no hydrolysis of their salts and no colloidally dissolved hydroxide to obstruct the passage of the light. Therefore the liquid remains optically clear.

Extremely suggestive, though preliminary in character and not directly connected with his other work, is Spring's proof that, in some way, the surface of a liquid is a seat of greater chemical activity than the interior portions.*

When a crystal of calcite dissolves partially in HCl, the crystalline form is not preserved. The angles are rounded off and grooves appear, especially in those surfaces which have been vertical or obliquely downward in the liquid so that the bubbles of CO_2 have had to slip along them on their way to the surface. This looks as though the presence of a gas bubble increased the action of the acid, and that

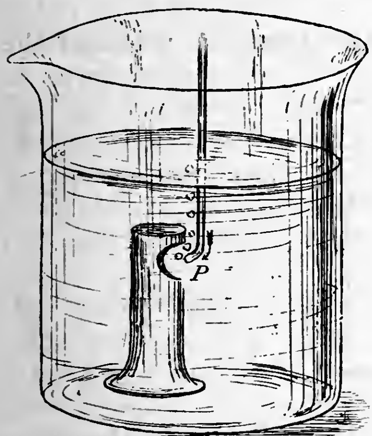

FIG. 1.

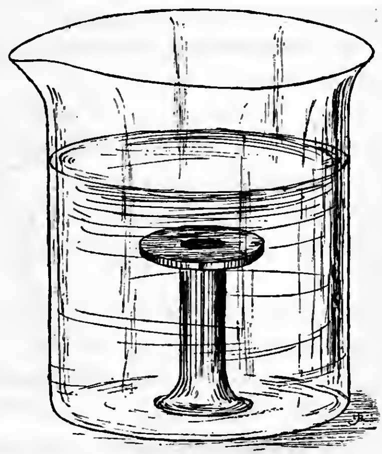
FIG. 2.

this is the case can be shown by supporting a slab of calcite vertically in HCl and leading a stream of CO_2 against it from a glass tube ending in a jet (*Fig. 1*).

A plate of calcite 2 m.m. thick is perforated at the point P, in a few minutes. This is not due to any chemical participation of the CO_2 in the reaction, for air and hydrogen produce exactly the same effect.

Probably the explanation that would occur to most people is that the gas current sets up a local vigorous stirring, constantly bringing new acid in contact with the

* *Zeit. Physikal. Chem.*, Vol. iv, p. 658.

surface. That this is not the true one can be shown by cementing a rim of wax to the upper end of a rod of calcite in such a way that the bubbles of CO_2 are held at rest (*Fig. 2*). The result is that the calcite next the wax is dissolved far more rapidly than the other portions, leading to a shape like that shown in *Fig. 3*.

Finally, if a slab of calcite is dipped half way beneath the surface of the acid, it is rapidly cut through at the surface of the liquid and the lower half falls to the bottom. The same behavior is shown by a liquid which only acts physically on a solid, for crystals of sugar, sodium carbonate and tartaric acid are rapidly cut in two by water under the same circumstances.

These remarkable facts were published in 1889, and the

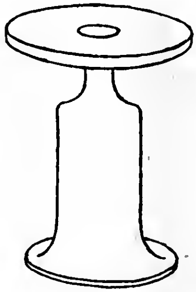

FIG. 3.

work seems well worth following up. So far as I am aware, nothing farther has been done upon the subject.

II.

The second line along which Spring's activity has been exerted, is a subject which has occupied much of his scientific career and to which he has returned again and again. Briefly, the matter may be stated thus: Many of the phenomena which we commonly associate exclusively with liquids and gases are manifested also by solids under the proper conditions of temperature and pressure, if time enough be given. The solid state is not a condition of total inactivity, but simply one in which change is slow—so slow that it may be overlooked. Among the phenomena

which he has shown to take place in solids are vaporization, crystallization, chemical action and the production of alloys and solutions.

Two cylinders of copper are placed base to base and held together by gentle pressure from a screw. The surfaces in contact have been most carefully polished and cleansed. They are heated to about 400° for twelve hours. This is far below the melting point of copper (1,100°). At the end of that time the union is so complete that when the mass is broken the fracture does not pass through the original junction. Cylinders of Al, Bi, Cd, Sn, Au and Pb behave in the same way, while cylinders of Sb and Pt adhere imperfectly or not at all.*

This shows that something like the liquid state occurs in metals long before they melt. The effect of pressure is similar. Powdered metals under a pressure of 10,000 atmospheres produce a mass which has all the appearance of having been fused. Rise of temperature produced by the pressure cannot be invoked to explain this fact, for it is easy to show that the elevation of temperature is very slight.

When cylinders of different metals are placed with polished surfaces in contact, and heated gently, they adhere firmly and alloys are formed at the point of junction. Thus with copper and zinc a layer of brass 18 millimeters thick is produced at the plane of contact. The following pairs behave similarly:

Cu — Cd
Cu — Sn
Cu — Bi
Fe —Zn

The time required is 4–8 hours, and the temperature, in all cases, much below the melting point of the most fusible metal present.

That copper and zinc vaporize below their melting points can be shown by making a depression in a zinc cylinder

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* *Zeit. Physikal. Chem.*, Vol. 15, p. 65.

and covering it with a copper one. When the pair is heated gently for a time, a very distinct layer of brass forms on the copper, and a brown stain containing copper on the zinc. This is not due to diffusion from the surfaces which are in contact, for when a ring of mica is placed between the two the result is the same.

When powders of different metals are compressed, alloys are formed:

$$Cu + Zn \text{ yield brass.}$$
$$Cu + Sn \text{ yield bronze.}$$

Mixtures of powdered sulphur or arsenic with finely divided metals yield sulphides and arsenides when powerfully compressed at ordinary temperatures. The combination of silver and sulphur is complete. Mixtures of zinc and sulphur appear to be unaffected.*

Naturally, under pressure the change takes that direction which is associated with decrease of volume. If a compound occupies more space than its constituents separately, it is decomposed by pressure. Thus the hydrate of arsenious sulphide ($As_2S_3\ 6\ H_2O$) separates into water and arsenious sulphide, and the double acetate of calcium and copper yields the single acetates.† Allotropic modifications of the elements obey the same law. Prismatic sulphur passes into the denser octahedral variety, and black amorphous arsenic is converted into the steel-gray crystalline modification, which has a higher density.

Solids which are not chemically altered by pressure are not in the least decreased in volume. When the pressure is relieved the original volume is exactly restored.

Powdered chalk when compressed becomes nearly as hard as marble.‡ Some powders, however, do not appear to become compact at all under pressure. Thus Al_2O_3, Fe_2O_3 and SiO_2 do not. It is important, geologically, that such substances can usually be made to form coherent masses by compressing the *wet* powder. The explanation of this is

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* *Bull. Acad. Belg.*, third series, 1883.

† *Zeit. Anorgan. Chem.*, Vol. 10, p. 185.

‡ *Zeit. Anorgan. Chem.*, Vol. 11, p. 160.

simple. A solution usually occupies a smaller bulk than the sum of the volumes of solid and liquid. Most solids dissolve with *contraction.* Hence, when a wet powder is compressed, the solution will be produced, since that will decrease the volume. Then, when pressure is relieved, some of the dissolved solid is abandoned by the liquid and deposited as a cement, which binds the grains of the powder together. On the contrary, a wet mass of potassium iodide or ammonium chloride does not at all cohere on compression since these solids dissolve with *expansion*, the volume of the solution being greater than that of solid and liquid.

From this brief résumé it is evident that Spring's work is qualitative and preliminary in character. Most of it will be gone over quantitatively, and the results expressed in tables and formulæ. But it deals with the foundations of our science, and one cannot deny to it a peculiar brilliancy of conception and execution which makes it of interest to all chemists, no matter what their special field may be, and even to educated men in general.

CENTRAL MANUAL TRAINING SCHOOL,
DEPARTMENT OF CHEMISTRY,
PHILADELPHIA, May 17, 1901.

A NEW METHOD OF TESTING THE VALUE OF LUBRICATING OILS FOR HIGH SPEED MACHINERY.

Many methods have been devised for testing lubricating oils, but those have heretofore been intended to indicate the value of the oils for journal bearings. A new device of this character has been invented by Dr. Sigmund Kapff and is described in one of the German engineering journals. It is specially adapted for the investigation of lubricants intended to be used with small bearing surfaces run at very high speed, such as spinning spindles, etc., and on a larger scale, with certain forms of high-speed wood-working machines.

The following description of the Kapff apparatus is abstracted from the *Engineering Magazine.* "The apparatus has neither belting nor gearing, the vertical spindle being driven by a small electric motor, at speeds as high as 8,000 revolutions per minute, while any desired pressure can be brought to bear upon the stop-bearing on which the spindle rests. Any desired lubricant can be used, and the work due to friction is indicated at any instant by the amount of current required by the motor. The spindle is entirely surrounded by an oil-chamber, and this in turn is enclosed in a jacketed cylinder which

prevents the escape of heat. A thermometer is inserted to indicate the temperature of the bearing for any known conditions.

"With this apparatus many properties of lubricating oils, not readily indicated by other testing devices, can be determined. Thus, many oils which show excellent results at moderate speeds, begin to work badly at 3,000 revolutions, and at higher speed. The oil seems to be entirely thrown off from the bearing, and a greatly increased frictional resistance appears. He finds, for example, as would be anticipated, that the higher speeds require oils of greater viscosity than the lower speeds; but this is found to be true within only certain limits (by taking successive mixtures of mineral oil and spindle oil, so as to obtain progressive gradations in viscosity). He shows that beyond a certain point an increase in viscosity requires an increase of work to overcome the friction.

"Proprietors of spinning mills and others employing very high speed machines would undoubtedly find it advantageous to employ some such service as this for the automatic testing of their lubricating oils." W.

THE LOSCHWITZ SUSPENSION CABLE RAILWAY.

A recent consular report gives the following interesting account of a small suspension railway lately opened for traffiic in Germany:

This new mountain railway was open to traffic May 6, and is the first of its kind for the conveyance of passengers. It runs from Loschwitz, a village on the banks of the River Elbe, about five miles from Dresden, to the top of the Rochwitz Heights, which command a most beautiful view of the Saxon capital. The railway is 820 feet long, and the grade is 32 per cent. It is constructed on the Langen system. The railways are carried by thirty-three hand-piers of varying sizes, the tallest being 49 feet high. Each car holds fifty passengers and weighs, when occupied, nearly 13 tons. Their shape and construction differ entirely from all other railway cars, even those used by the Barmen-Elberfeld Suspension Railway. The two trains of cars are connected by a steel cable 1·7 inches in diameter, and they are moved back and forth by two engines of 80 horse-power each. Safety appliances are numerous and efficient. Visible and audible signals serve to regulate the arrival and departure of the trains, and these signals are operated both from the upper and lower stations. Each car is provided with a danger signal apparatus consisting of an alarm and a telephone which enables the conductor to communicate from any part of the road with the engine house. The car is provided with three brakes, two of which work automatically at the least slackening of the tension of the cable and stop the car. An indicating device in the engine room shows at all times the exact position of the cars, and a bell warns the attendant if the train is running too fast. An automatic brake, both at the top and lower station, is put into action by the arriving car, and stops it even if the engineer is careless. A roundtrip ticket costs less than 6 cents; the journey requires only 3 minutes, and 15,550 passengers can be carried each way per day.

An Investigation of the Cost of Power.*

By Clyde D. Gray.

Continued from p. 275.

THE STEAM BOILER.

Steam boilers are of many types and kinds but they may be generally divided into two great classes that are the most used in American practice: The tubular or fire-tube, in which the water is on the outside of the tubes or flues and the heated gases on the inside, and the water-tube, in which these conditions are reversed. Each of these classes has many forms, but those most commonly used are the horizontal return tubular, in which the fire is under the outside of the shell at the front end, the heated gases passing to the rear under the shell and then returning to the front through the flues and thence out of the smoke flue, and the straight inclined-tube water-tube type, in which the water is inside the tubes and the heated gases circulate around them, the Babcock & Wilcox, Heine and Root being examples of this class.

The water-tube type is being extensively used at the present time because of its greater immunity from explosion, economy of floor space, ease with which it may be cleaned and repaired, and the ability to carry the higher pressures of steam that are being demanded. The first cost of this type was formerly much higher than that of the tubular boiler; but now the cost has been reduced to such an extent, owing to increased facilities for manufacturing, that they can be purchased for nearly the same price as the other class.

The results of some boiler tests are given in the table below, showing the kind of boiler, pressure, kind of fuel used and the equivalent evaporation of water from and at 212° F. per pound combustible.

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* From thesis presented for the degree of master of mechanical engineering. Sibley College, Cornell University. 1901.

WATER-TUBE BOILER TESTS.

Kind.	B. H. P.	Press. Lbs.	Water Evap.	Fuel.	Authority.
B. & W.	667	225	8·65	Anth.	Baldasano and Beach on Edison El. Ill. Co., N. Y.
"	315	225	11·32	"	
"	293	225	10·01	"	
"	362	225	10·60	"	
Worthington . .	143	93	11·23		Jacobus, *S. R. J.*, Jan., 1899.
" . .	227	96	9·87		
Campbell . . .		110	9·18		Willis, *S. R. J.*, Dec., 1899.
Stirling	551	132	10·98		*St. Ry. Jour.*, May, 1899.
"	206	132	10·43		
B. & W.		128	8·00	(on dry bit. coal)	Buffalo Ry. Plant, 1900.
National	534	80	11·87		Whitham, A.S.M.E., 17–582.
" . . .	902	102	11·81		
B. & W.	154	89	11·00		
"	500	102	11·38		
"	553	130	11·69	Buck'wt	
"	370	132	11·31	"	
"	581	133	11·00	"	
"	260	87	11·76	"	
"	348	85	12·19	"	
Root	168	127	10·96	"	*Sib. Jour.*, 8–341.
B. & W. (marine)		200	12·25	(nat. d. heated)	Mellville *Cass. Mg.* 15–251.
" "		200	11·02	(forced heated)	
" "		200	9·35	(forced cold)	
Root	120		12·09	Anth.	Centennial test, Kent 685.
B. & W.	136		11·82	"	
"	96		12·46	A. scr. ·2 Bit. ·8	A.S.M.E., 4–267.
"	250		9·29	Slack	
"	419		11·00	Lump	
"			11·54	Oil	14–1082.
Not given	55	89	10·61	Anth.	Barrus, "Boiler Tests."
" "	475	101	11·44	Pea	
" "	133	73	9·68	Anth.	
" "	47	104	10·00	"	
" "	244	67	10·79	Bit.	
" "	74	84	10·36	Anth.	
" "	166	62	10·93	Bit.	
" "	189	73	10·98	"	

PLAIN TUBULAR BOILER TESTS.

Kind.	B. H. P.	Press. Lbs.	Water Evap.	Fuel.	Authority.
Horizontal . . .		112	11·67		A.S.M.E., 16–49.
" . . .		74	7·54	Lump	" 16–773.
" . . .	132	102	10·26		Whitham, A.S.M.E., 17–582.
" . . .	936	97	11·14		
Return		90	9·92	(on pea coal)	Denton, A.S.M.E., 12–975.
Horizontal . . .	507	117	11·95	1 slack 2 culm	Carpenter, *Sib. J.* 7–9.
" . . .	386	105	10·50	1 slack 1 screen.	
" . . .		97	8·24	Pea	Vail, A.S.M.E., 20–157.
Vertical		112	11·36		Stone and Webster, *St. Ry. Jour.*, Aug., 1898.
Horizontal return,	79	73	10·25	Anth.	Barrus, "Boiler Tests."
" direct,	93	72	10·85	"	
" return,		116	10·55	Bit.	
" "	345	85	10·73	Anth.	
" direct,	106	70	10·73	Mixed	
" return,	68	56	10·23	"	
" "	78	63	10·74	"	
" "	135	81	9·79	Culm	
" "	129	81	9·49	"	
" "	196	63	11·33	Anth.	
" "	155	79	11·00	"	
Vertical	85	73	8·61	"	
"	94	73	10·27	Bit.	
Horizontal return,	359	83	11·11	Anth.	

MISCELLANEOUS BOILER TESTS.

Kind.	B. H. P.	Press. Lbs.	Water Evap.	Fuel.	Authority.
Portable	40	70	7·90	. . . .	Webber, A.S.M.E., 13–413.
"	63	70	9·80		
Galloway			11·22		Centennial test.
Vert. fire-tube .		142	10·67		*Sibley Journal*, 9–323.
Manning, vert. .		153	10·40	(on coal)	Barrus.
Thornycroft . . .		250	11·90	" "	Mellville, *Cass. Mg.* 15–251.
Cylinder	82	97	7·97	Anth.	Barrus, "Boiler Tests."
Cast Iron Sec. . .	38	28	9·78	"	
" " " . .		82	9·26	"	
Belleville		111	10·52	Bit.	Leonard, A.S.N.E., 1890 (Kent, p. 686).
Thornycroft . . .		245		"	
Herreshoff . . .		120	10·23	Anth.	

SUMMARY OF TESTS.

Authority.	No. of Tests.	Water Evap.	Kind of Fuel.
Kent (Christie) A.S.M.E., 18–365	95	11·11	All kinds.
Barrus, horizontal tubular	16	10·76	Anthracite.
" " " low flue temp.	6	10·40	Anthracite.
" " " high " "	5	11·0	Anthracite.
" " "	10	11·59	Cumberland.
Average from above tables, W. T.	37	10·80	All kinds.
" " " " tubular	23	10·40	All kinds.
Average of all the above	192	10·86	

From the above tables and summary, it is clear that the efficiencies of different kinds of boilers are nearly the same irrespective of the kind of fuel or the rate of combustion. Kent in his compilation of Christie's tests gives a table in which he shows that the evaporation is independent of the rate of combustion of the fuel per unit of grate surface. (A.S.M.E. 18–365.) Mr. LeVan in the same place says that, in his experience of about four hundred boiler trials, the efficiency has not advanced since the time of the tests made at Philadelphia in 1876. This fact is sustained by other writers also.

Mr. Barrus gives the following table showing the evaporation by different kinds of coal, taking an evaporation from and at 212° of 11 pounds of water for anthracite broken coal as the standard, rated on the combustible:

Kind of Fuel.	Equiv. Evap. Per Lb. Dry Coal.
Anthracite, broken	9·79
Cumberland, bituminous	11·04
Anthracite, chestnut	9·40
" pea	8·86
2 parts pea and dust, 1 part Cumberland	9·38
" " " " " " " culm	9·01
Nova Scotia culm	8·42

Mr. McClave, of Scranton, Pa., read a paper before the Anthracite Coal Operators' Association on January 9, 1895, in which he gave the relative values of anthracite and bituminous coals for steam raising and also the per cent. that would have to be added in weight to the different kinds to bring them up to the standard of anthracite egg.

M'CLAVE'S TABLE.

Kind of Coal.	Value. Per Cent.	Per Cent. to Add.
Bituminous coal, good quality	100	
" slack " "	90	11·1
Anthracite, steamboat, good quality	95	5·3
" broken " "	97	3·1
" egg " "	100	
" stone " "	100	
" chestnut " "	100	
" pea " " well cleaned	95	5·3
" " mixed with bone and slate	90	11·1
" buckwheat, No. 1, good quality	93	7·5
" " " 2 " "	85	17·6
" " " 3 " "	83	20·5
Anth. culm mixed with 20 per cent. soft slack, good qual.,	83	20·5
" " No. 2 " " " " " " " "	77	29·9
" " " 1 alone, good quality	75	33·3
" " " 2 " " "	70	42·9

OIL AS A FUEL.

Oil has been used to a certain extent as a fuel but its use is restricted to the locality of oil wells and even there it cannot compare in economy with coal at the average prices.

In a test by the Twin City Rapid Transit Company, of St. Paul and Minneapolis, it was found that with ordinary Lima oil weighing 6·6 pounds per gallon and costing 2.25 cents per gallon, and coal that gave an evaporation of 7·5 pounds of water per pound of coal, it cost $3.85 per ton of 2,000 pounds, including all costs of handling the oil, coal and ashes. (*Iron Age*, November 2, 1893.)

At the South Chicago Steel Works a test was made which showed that 3·22 barrels of oil equivalent to a ton of coal in steam raising and with oil at 60 cents per barrel and coal at $2.15 per ton, the relative cost of oil to coal was as 1·93 to 2·15. (A.I.M.E. 17–817.)

The evaporative power of oil given by Pike and Hugo, as the results of tests, was 11·54 pounds of water per pound oil at St. Paul and 11·87 at Minneapolis. (A.S.M.E. 14–1082.)

Mr. Barrus, in his book on boiler tests gives, in one case, an evaporation of 11·96 pounds of water, another of 13·66 pounds with petroleum residue, and one of 15 pounds with Canada oil. He says that the cost of oil must be less than $1 per barrel to compete with Cumberland coal.

ENGINE TESTS.

SIMPLE AUTOMATIC, NON-CONDENSING.

Kind or Use.	Press.	I. H. P.	Steam Per H. P.	Authority.
	90	26	25·0	Hirn, A.I.E.E., 10–287.
	87	76	30·9	Carpenter, " "
Electric power . . .		88	34·6	Hensen & Riker, *Sib. Jour.* 11–97.
Schmidt	127	23	14·8	Thurston, A.S.M.E., 18–820.
		21	44·1	Carpenter, A.S.M.E., 14–426.
		83	33·6	
		76	31·0	
		455	30·9	11–723.
	82		30·6	Barrus, A.S.M.E., 9–545.
	77		29·0	
	90		29·3	
	72		27·8	
	100		25·8	
Semi-port	61	5	65·0	Unwin, *Cass. Mag.*, 5–353.
Small		13	41·0	
"	35	6	44·0	Donkin, *Cass. Mag.*, 5–353.
Willans	44	9	41·8	Willans, *Cass. Mag.*, 5–353.
" slow . . .	112	20	30·2	
" fast	36	16	42·8	
" "	74	26	32·6	
" "	122	34	26·0	
Mill	76	310	25·6	Barrus, "Engine Tests."
Electric light . . .	103	53	32·7	
" " . . .	105	27	34·0	
Test	92	45	32·6	
Cotton mill	68	209	28.6	
Factory	65	32	40·0	
Woolen mill	80	62	32.7	
Shop	74	71	29·4	
	72	38	37·2	
Average			33·4	

SIMPLE CORLISS, NON-CONDENSING.

Kind or Use.	Press.	I. H. P.	Steam Per H. P.	Authority.
	90		29·3	Barrus, A.S.M.E., 11–153.
	68		34·0	
Reynolds	97	137	23·9	Hill, *Cassier's Mag.*, 5–353.
Harris	96	134	22·0	
Wheelock	96	140	24·9	
Mill	72	305	27·8	Barrus, "Engine Tests."
"	101	506	25·8	
"	99	342	25·9	
"	81	232	29·0	
Average			28·9	

COMPOUND AUTOMATIC, NON-CONDENSING.

Kind or Use.	Press.	I. H. P.	Steam.	Authority.
Shop test	100	56	22·1	Thurston, A.S.M.E., 18–988. 16–838.
" "	100	55	25·7	
	90	64	26·2	
		114	23·8	Carpenter, A.S.M.E., 14–426.
		111	23·1	
Shop test			25·4	Bole, A.S.M.E., 12–275.
Service test			22·4	
		70	32·8	Carpenter, A.S.M.E., 11–723.
Willans, slow	89	10	27·0	Willans, *Cassier's Mag.*, 5–353.
" "	103	11	24·7	
" "	120	13	23·4	
" fast	114	33	21·4	
" "	135	36	20·4	
" "	165	40	19·2	
Buckeye	125	180	20·4	Mansfield, A.S.M.E., 20–243.
Electric light	128	231	22·5	Barrus, "Engine Tests."
" "	128	153	25·2	
" "	136	110	22·9	
	118	267	23·2	
	129	347	22·1	
Dynamo	165	243	21·3	
Average			23·6	

SIMPLE AUTOMATIC, CONDENSING.

Kind, Use.	Press.	Vac.	I. H. P.	Steam.	Authority.
Mill	79	23·6	336	20·5	Barrus, "Engine Tests."
Cotton mill,	67	25·5	213	22·1	
" "	75	24·8	205	27·2	
Factory	68	23·0	444	23·0	
Mill	82	27·9	613	18·5	
El. light	83	26·7	206	21·4	
Average				22·2	

SIMPLE CORLISS, CONDENSING.

Kind, Use.	Press.	Vac.	I. H. P.	Steam.	Authority.
			62	28·7	Carpenter, A.S.M.E., 11–723.
	66			19·9	Barrus, A.S.M.E., 11–153.
	50			24·3	
	85			19·2	
	83			18·5	
Corliss	61			19·3	Langridge, *Cass. Mag.*, 5–353.
Harris	96		166	19·4	Hill, *Cass. Mag.*, 5–353.
Reynolds	96		163	19·5	
Wheelock	96		158	19·3	
Sulzer	75		395	19·7	Linde, *Cass. Mag.*, 5–353.
"	87		284	18·4	
"	90			19·0	Linde, *Eng. Mag.*, 10–853.

Kind, Use.	Press.	Vac.	I. H. P.	Steam.	Authority.
Corliss	62		137	17·5	Thurston, *E. W.*, Jan. 5, 1901.
Mill	70	24·2	554	19·5	
Factory	67	26·2	211	21·1	
Mill	68	29·8	362	18·7	Barrus, "Engine Tests."
"	71	26·7	758	18·3	
"	70	21·0	258	23·6	
Average				20·2	
COMPOUND AUTOMATIC, CONDENSING.					
Marine	110		534	17·9	A.I.E.E., 10–287.
"	115		132		Stebbins, *Sibley Jour.*, 9–341.
El. Railway	127			21·7	Manning, " " 9–370.
" "	124			22·5	
Schmidt	165		112	10·6	Thurston, A.S.M.E., 18–820.
"	159		70	9·6	" " "
	90		64	26·2	" " 15–838.
Shop test	100		56	17·5	" " 18–988.
" "	100		55	20·6	" " "
El. Railway			523	29·3	Pike & Hugo, A.S.M.E., 14–1,082.
" "	118		783	23·5	
			89	19·2	
			95	19·1	Carpenter, " 14–426.
	130		95	18·8	11–723.
Portable	101		6	35·7	Unwin, *Cass. Mag.*, 5–353.
Marine			371	21·2	Kennedy, " " "
Marine	165		1979	21·7	
El. light	129	25·0	228	18·9	
" "	105	28·0	149	22·0	
" "	121	27·0	221	18·0	
Cent. pump	126	21·1	348	18·2	Barrus, "Engine Tests."
El. light	130	25·5	197	19·1	
" "	120	25·1	296	16·1	
Willans	165			14·3	Willans, *Eng. Mag.*, 10–853.
Average				19·8	
COMPOUND CORLISS, CONDENSING.					
Railway	112		709	15·1	Stone & Webster, *S. R. J.*, Aug., '98.
"	110	26·0	469	14·3	Willis, A.I.E.E., 1899.
"	150		600	14·5	*Cassier's Mag.*, Feb., 1901.
"	112	26·5	373	13·8	Willis, A.I.E.E., 1899.
"			200	17·6	*Cassier's Mag.*, Feb., 1901.
"	115		400	23·0	*Sibley Journal*, 11–93.
"	105		483	23·2	" " 8–393.
Mill	117		1,001	16·3	" " " (R.C.C.).
Railway	81		80	27·3	" " "
	155		1,950	12·5	Thurston, *Science*, Oct. 1, 1897.
El. light	109	25·0	189	20·5	Christie, A.S.M.E., 19–301.
Cotton mill	123	27·1	1,076	12·8	Dean " "

Kind, Use.	Press.	Vac.	I. H. P.	Steam.	Authority.
Sibley . .	115	22·8	129	15·8	Thurston, A.S.M.E., 19–152.
El. light . .	90		137	20·9	" " 15–838.
Mill . . .	100		999	21·1	" " "
" . . .	100			13·3	" " "
Wheelock .	145			13·1	Denton, " 14–1,340.
Mill . . .	151		997	12·8	Barrus, " "
	123	25·6	1,592	13·5	Thurston, " 15–839.
	120		1,018	13·3	Barrus, " "
Railway .	112		70	24·6	
Mill . . .	159	25·4	595	12·7	Dean, " 16–169.
				16·6	Carpenter, " 11–723.
Wetherill .				16·3	
Sulzer . .				14·1	
" . .				13·7	Main, A.S.M.E., 10–48.
				15·8	
				18·9	
Mill . . .	53		57	20·5	Donkin, *Cass. Mag.*, 5–393.
" . . .	87		888	17·8	
" . . .	87		862	19·8	Longridge, " " "
" . . .	95		314	17·0	
" . . .	95		338	17·2	
Sulzer . .	90		267	14·0	Sulzer, " " "
	90		135	15·3	Uincotte, " " "
	110		272	15·3	Soldini, " " "
Dujardin .	90		548	13·5	
Sulzer . .	85		247	13·4	Thurston, *E. W.*, Jan. 5, 1901.
Wheelock .	160		590	12·8	
Railway .	130	26·2	534	16·1	*St. Ry. Journal*, May, 1899.
Mill . . .	147	27·1	524	14·5	Longridge, *Mech. Mag.*, October 13–1899.
" . . .	148	27·2	521	13·9	
Cotton mill	95	27·2	607	16·3	
" "	116	25.5	637	13·3	
El. light .	127	27·4	384	14·1	
Factory . .	108	27·0	280	13·4	
Cotton mill	151	27·0	689	12·7	
" "	126	27·0	1,107	14·1	
" "	115	28·4	873	14·2	
" "	108	27·2	798	13·3	Barrus, "Engine Tests."
" "	150	26·9	1,713	12·3	
" "	144	25·2	741	13·2	
Factory . .	115	25·6	300	15·8	
El. light .	151	26·8	1,713	13·3	
" " .	108	25·2	676	14·6	
Cotton mill	133	25·2	1,539	14·1	
Dynamo .	136	26·2	1,030	13·2	
Average				15.74	

TRIPLE CORLISS, CONDENSING.

Kind, Use.	Press.	Vac.	I. H. P.	Steam.	Authority.
	141		125	13·7	Peabody, A.I.E.E., 10–279.
El. light .	142		475	15·3	*Sibley Journal*, 9–323.
Sibley . .	119	24·3	113	13·7	Thurston, A.S.M.E., 19–152.
Mill . . .	150	26·9	671	12·4	Barrus, " "
El. light .	160			15·0	Report of N.E.L.A. for 1897.
Mass. Tech.	143	25·0	102	15·0	*Trans.*, A.S.M.E., 16–89.
" "	145	26·2	102	13·3	
Augsburg .	88			13·4	Schröter, " "
Wheelock .	140			13·0	Denton, " 14–1,340.
Boston Ry.,	158		973	12·3	Mann & Larkins, "
Mass. Tech.	90		150	16·3	Table in *Trans.* A.S.M.E., 15–838.
" "	88			14·7	
	156		200	12·7	Schröter, " "
Sulzer . .	150		1,200	11·7	Hill, A.S.M.E., 18–795.
" . .	155	27·0	1,870	11·3	
" . .	168		631	10·8	
" . .	168		735	10·7	
	145		200	12·6	Jacobus, " 11–275.
El. light .	125	26·5	532	12·9	Henthorn, " 11–643.
				18·6	Carpenter, " 11–723.
Willans . .	172		39	18·5	Willans, *Cass. Mag.*, 5–353.
Sulzer . .	145		360	11·7	Sulzer, " " "
" . .	156		198	12·2	Schröter, " " "
Augsburg .	145		700	12·5	
Marine . .	145		1,994	15·0	Kennedy, " " "
" . .	144		1,087	19·8	
" . .	165			13·3	" " *Eng. Mag.*, 10–853.
	192			12·7	Reynolds, " " " "
Willans . .	175			12·7	Willans, " " " "
Sulzer . .	141		615	11·9	Thurston, *Elec. W.*, Jan. 5, 1901.
Reynolds .	120		574	11·7	
Leavitt . .	185		576	11·2	
Snow . . .	156		773	11·3	
Ringhoffer,			805	10·9	*London Eng.*, Mar. 8, 1901.
"			653	10·6	
Cotton mill	151	27·0	997	12·7	Barrus, "Engine Tests."
Average				13·3	

QUADRUPLE, CONDENSING.

Hall-Treat.	300		16	10·8	Thurston, *Elec. W.*, Jan. 5, 1901.
"	400		16	9·7	
"	500		16	9·8	

STEAM TURBINES.

Kind.	Press.	Vac.	D. H. P.	Steam.	Authority.
Laval . . .	100			21·3	Ewing.
" . . .	130		11	47·8	Goss, A.S.M.E., 17–83.
" . . .	115	26·0	64	19·7	Cederblom, A.S.M.E., 17–83.
W'stingh'se	125	26·5	400	12·2	*Elec. World.*, Jan. 5, 1901.
Parsons . .	162		1,330	15·0	*Sci. Am.*, Jan. 12, 1901.
" . .	130		1,610	14·0	*Elec. World*, Jan. 5, 1901.
Laval . . .			300	15·8	
Dow . . .				45·0	*Sci. Am.*, Jan. 12, 1901.
Curtis . .	130	28·0		25·0	
Parsons . .	127	24·8	800	16·7	Baker, *Elec. World*, p. 313, 1900.
" . .	139	24·5	705	18·0	
Laval . . .		145	26·0	19·3	Edison El. Ill. Co., 1896.
Parsons . .		0·		30·9	*Lond. El. Review*, Feb. 19, 1897.
" . .		Cond.		19·5	

PUMPING ENGINES.

SIMPLE.

Kind, Place.	Pressure.	I. H. P.	Steam.	Duty in Millions.	Authority.
Lawrence . . .			16·5	112	
Beam	45	120	21·3		Mair, *Cassier's Mag.* 5–353.
"	42	123	22·0		Longridge, " "
Average			19·9		

COMPOUND.

Kind, Place.	Pressure.	I. H. P.	Steam.	Duty in Millions.	Authority.
Wolff	106		12·7		Denton, A.S.M.E., 14–1340.
"	125	313	13·5		Jacobus, " "
Louisville . .	137	643	12·2	138	Dean, " 16–169.
Worthington .	88	443	17·0	109	Denton, " 12–975.
Pawtucket . .	125		13·6		" " 11–328.
	94	607	16·3		Barrus, " 9–545.
	100		14·7		Coon, " "
	70	177	20·9		
	61	127	14·8		Mair, *Cassier's Mag.*, 5–393.
Worthington .	75	296	17·4		
	60	255	17·7		
Beam	99	252	13·9		Leavitt, " " "
"	99	290	14·2		
Average			15·3		

TRIPLE.

Kind, Place.	Pressure.	I. H. P.	Steam.	Duty. Lbs. Coal Per I. H. P.	Authority.
Worthington .	150	294	14·4		*Power*, November, 1900.
Boston	186	801	14·5	157	*London Eng.*, Sept. 2, 1900.
	126	574	12·6		Barrus, "Engine Tests."
	151		13·4	125	Denton, A.S.M.E., 14–1,340.
Milwaukee . .	121	573	11·7	138	Carpenter, " "
Chicago . . .	120	1,092	12·0	135	Hunt, " "
Trenton . . .	112	235	13·4	118	*Transactions*, A.S.M.E., 16–49.
Allegheny . .	180	294	13·8	129	
Detroit		574	12·5	130	
St. Louis . . .		813	10·8	155	
" . . .		802	10·7	159	*Journal* A.E.S., July, 1900.
Chestnut Hill .		576	11·2	142	
Buffalo		1,185	12·4	135	
Indianapolis .		776	11·3	150	
Average				12·3	

QUADRUPLE.

Nordberg . . .	200	712	12·3	163	Carpenter, *Sib. Jour.*, 13–76.

SUMMARY OF ENGINE TESTS.

SIMPLE, NON-CONDENSING.

Authority.	Aut.	Corliss.
Carpenter (Sibley theses, *Sib. Jour.*, 14-228)	34·3	28·3
L. Bell, "Electrical Transmission of Power"	33·0	28·0
Hutton, "Mechanical Engineering of Power-plants" .	33·0	29·0
Thurston & Carpenter, A.I.E.E., 10–297	31·5	28·6
Davis, C. H., *Engineering Magazine*, 12–942. . . .	36·0	31·5
Average of my tables	33·4	28·9
Average of all above	33·8	29·0

COMPOUND, NON-CONDENSING.

Carpenter	32·3	
Bell	24·0	22·0
Hutton	26·0	24·0
Thurston & Carpenter	24·5	
Davis	27·0	26·0
Tables	23·6	
Average	26·2	24·0

SIMPLE, CONDENSING.

Carpenter		
Bell	25·0	21·0

Authority.	Aut.	Corliss.
Hutton	22·0	20·0
Thurston & Carpenter		23·0
Thurston, *Engineering Magazine*, 7–844		25·0
Davis	31·0	26·5
Tables	22·2	20·2
Average	23·1	22·6
COMPOUND, CONDENSING.		
Carpenter	22·7	18·3
Bell	20·8	18·0
Hutton	20·0	18·0
Thurston & Carpenter	18·8	17·2
Davis	22·5	23·0
Thurston		18·0
Tables	19·8	15·7
Average	20·6	17·7
TRIPLE, CONDENSING.		
Carpenter		
Bell	17·0	13·0
Hutton	17·0	16·0
Thurston & Carpenter		14·6
Thurston		14·0
Tables		13·3
Average	17·0	14·2

PUMPING ENGINES.

	Simple.	Compound.	Triple.	Quadruple.
Average of tables	19·9	15·3	12·3	12·3

The above are all condensing and are generally for the larger sizes of pumping engines.

The above summary serves to show the results obtained from my collection of tests and compares them with tables of average performance as given by other authorities. It may be seen that they check fairly well with the other tables.

STEAM PLANT COSTS.

The cost of steam plants vary greatly with the locality, size, kind of machinery, boilers and many other items. The table given below may serve to show what such costs have been in the past as recorded in the different engineering literature. It may be considered to be a very good approximation to the actual cost of such construction.

TABLE OF PLANT COSTS.

Authority.	Cost Per H. P.	Remarks.
Manning, A.S.M.E., 10–48 . .	68·26	Total, engine, boilers, stack, 500 horse-power plant.
" " " . .	52·50	Same, 1,000 horse-power plant.
Field, C. J., " 16–504 . .	50·00	Steam plant complete.
Webber " 17–41 . .	65·00	Plant complete.
" " " . .	54·71	High speed condensed, from Emery's tables for 550.
" " " . .	59·51	Low speed from Emery.
" " " . .	60·35	Comp. low, " "
" " " . .	70·00	Triple comp.," "
Dean, " 19–301 . .	70·00	Simple Corliss cond., best, 1,000 h. p.
" " " . .	57·00	Comp. cond., best, 1,000.
" " " . .	60·50	Actual cost of a yarn mill, 1,132 h. p.
Rathwell, A.I.M.E., 17–555 . .	40·00	Engines and boilers.
Western Elec., Mar. 16, 1901 .	60·00	Complete plant.
Carpenter, *Sib. Jour.*, 14–298 .	28·60	Simple slide-valve, non-condensing.*
" " " " .	30·20	Corliss, non-condensing.
" " " " .	30·00	Comp, slide-valve, non-condensing.
" " " " .	30·00	Non-condensing cond.
" " " " .	33·25	Comp. Corliss, cond.
Elec. World, Feb. 2, 1901, 214 .	28·50	Estimates on plant for South Africa.
Thurston, *Eng. Mag.*, 7–844 .	38·00	Engines, boilers and piping, simple cond.
" " " " .	45·00	Compound cond.
" " " " .	53·00	Triple cond.
" " " " .	62·00	Quadruple cond.

Field in A.S.M.E. 16–504, gives the average cost of steam plants as ranging from $50 to $55 per horse-power and Professor Ryan in an article in the *Engineering Magazine*, 7–733, says that the cost of steam plants with high speed engines is about $50 and that for slow speed Corliss engines ranges from $65 to $75. This is exclusive of the cost of the buildings.

The costs of electric plants are dependent upon the cost of engines and boilers and their cost is usually a constant quantity, for the cost of dynamos is nearly constant per kilowatt plus the cost of engine plant. The cost of dynamos and other electrical apparatus may be assumed as ranging from $20 to $35, including switchboard. Hence the cost of complete plants for electric lighting and power may be

* The costs under this are for engines, boilers and piping alone, exclusive of cost of building.

assumed to cost from $75 to $100, dependent upon circumstances.

COST OF STEAM POWER.

The cost of generating steam power is extremely variable and depends upon many factors among which may be mentioned, the kind and steadiness of load, the hours of service per day, the kind of engines, quality of fuel, efficiency of boilers and engines.

A few figures relating to the cost of steam power are given in the table below. These are taken from different sources and show the cost under various conditions.

TABLE.

Authority.		Fixed Cents.	Operating.	Total.	Time.
Emery, A.I.E.E., 12–358		0 09	0 23	0 31	Continuous.
Gerry, " 14–353				37	Ry. plant.
Foster, A.I.E.E., 14–385	S-S-N	38	1 52	1 90	6 cases.
	S-H-N	44	2 44	2 88	4 "
	S-S-C	11	78	90	1 "
	Pump	74	1 18	1 92	3 "
	C-S-C	25	57	82	4 "
	T-S-C	19	32	51	1 "
	S-H-N	12	85	97	From Emery's table.
	S-S-N	12	74	86	
	C-H-N	11	70	81	
	T-H-N	11	65	77	
	S-H-C	16	61	77	
	S-S-C	11	55	66	
	C-H-C	10	57	67	
	C-S-C	11	51	62	
	T-H-C	10	51	61	
	T-S-C	12	47	59	
	"	13	45	58	
		21	43	64	Webber, yarn mill.
		22	51	73	
		21	35	56	Hale, yarn.
		17	54	71	May, pump.
	Compound	20	44	64	Main, 3,157 hours per year.
	Condensing	20	55	75	
	High-pressure	21	63	83	
Elec. World, *Dg. Eng. Mag.*, Feb., '00				90	In Italy.
C. J. Field, *Cass. Mag.*, Mar., 1896				92	Triple cond.
Sci. Am., Oct. 6, 1900	Oil fuel			2 90	Non-cond.
	" "			2 40	Condensing.
Main, A.S.M.E., 13–140		26	42	68	500 h. p.

Authority.		Total.	Time.
Brown, *West. Elec.*, Feb. 23, 1901		0 50	3,080 hours.
		32	Continuous.
May, A.S.M.E., 15–1,147	Manning's data	58	Continuous.
	Main's "	59	Continuous.
	Milwaukee pump	63	6,980 hours.
	Triple pump	63	Continuous.
	Same	1 04	3,180 hours.
	Comp. mill	53	Continuous.
	Same	79	3,180 hours.
	Electric light compound	1 59	Continuous.
	Same	2 64	3,180 hours.
	Electric railway compound,	66	Continuous.
	Same	1 00	3,180 hours.
	Triple, electric railway	62	Continuous.
	Same	91	3,180 hours.
	Non-condensing	87	Continuous.
	Same	1 67	3,180 hours.
Average of all above		95	
" neglecting those over 1.0 cent		72	

The tables given by Foster are perhaps the most reliable of the recent data on the subject. In these tables, he has worked out the costs for a year of 7,300 hours from the data and estimates of Dr. Emery given in *Trans. A.I.E.E.*, March, 1893. His own figures are from actual cases. The letters used to denote the different kinds of engines are to be read thus: *e. g.*, S-S-N. Simple, slow speed, non-condensing. H is for high speed, C for compound and condensing and T for triple engines.

Mr. Foster gives a very interesting table of the cost per horse-power hour of power generated by large compound condensing engines as estimated by different authorities. This table is given below as well as the average of my table.

Authority.			Cost Per H. P. Hour Cents.
Emery,	A.I.E.E.,	for 3,080 hours per annum	0.784
"	"	" 7,090 " " "	.617
"	*Eng. Mag.*,	" 3,080 " " "	.856
Webber,	650 h. p.,	" " " " "	.720
"	1,050 "	" " " " "	.646
Hale,		" 2,985 " " "	.557
Main,		" 3,080 " " "	.637
Foster,		" " " " "	.824
My table			.720
Average of all			.707

Mr. Louis Bell in his book, "Electrical Transmission of Power," gives as the cost for 10-hour day, full load with large compound condensing engines, ·8 to 1·0 cents per horse-power hour and for simple engines, 1·5 to 2·5, while if the load is partial and intermittent, these figures become 1·0 to 1·5 3·0 to 4·0 respectively.

The cost of engines varies considerably with the class, but the following table is a very good approximation for the different kinds:

Simple slide valve engine	$7 to $10
" Corliss or low speed type	11 " 13
Compound slide valve	12 " 15
" Corliss	18 " 23
High speed automatic	10 " 13
Low " "	15 " 17

In addition to this is the price of boilers which is approximately $10 to $12 for the plain tubular and about $15 for the water-tube type and the cost of pumps which is about $2 for a non-condensing and $4 for a condensing plant, including heaters.

The costs given are often modified greatly for specific cases depending upon the amount of competition for the contract and other variables of a like nature, so that it is difficult to give more than approximate prices on anything of this kind.

GAS ENGINES.

The gas engine is coming into use at the present time as a rival of the steam engine, especially in the smaller sizes and for such purposes where an intermittent source of power is required, for there is no loss while the engine is standing idle as there is in the case of the steam engine. The great disadvantages of the gas engine are being overcome to-day, so that it will do the work of the steam engine in almost all cases. The regulation was the great drawback to the general adoption of the gas engine, especially for electrical work, the old single cylinder, four cycle, hit-and-miss ignition not being good for such use; but now, with the adoption of the electrical ignition and throttling

governor, together with the employment of more than one cylinder, so that there is an explosion oftener than once in every two revolutions, the gas engine is a serious rival of the steam engine in many cases.

The advantages of the gas engine are: Small amount of space required for a given output; ease of managing, cleanliness; a cheaper grade of coal may be used for fuel in the gas producer than in the boiler and more of the heat utilized; no expense while engine not running; the thermo-dynamic efficiency is much higher than that of the steam engine; it may be run on waste gases from blast furnaces, thus making the item for fuel a nominal one, and, in regions where natural gas is obtainable, it is much cheaper than the steam engine.

Some of the disadvantages are: The liability of its getting out of repair or adjustment, so that it is not as reliable for general rough usage as the steam engine. The greater cost per horse-power sometimes stands in the way of its installation—where steam has to be generated for other purposes than power, of course it cannot compete with the steam engine—it cannot be made in very large units, although engines up to 1,000 horse-power are common; it does not regulate quite closely enough for the operation of alternators in parallel, which is a common requirement at the present time; and, lastly, there is a prejudice against its use that is hard to overcome.

It seems fitting to begin the discussion of the gas engine with some values of the different kinds of gas that are used. There are several kinds of gas that are good for this purpose, natural gas being the best as it has the highest heating value per unit volume. Next comes the ordinary coal gas, such as is made for commercial lighting. Then water gas and producer gas which are made from coal, water and air being passed through the furnace while the coal is burning, in small amounts, and, lastly, waste gas from blast furnaces, which is very low in heating value, so that special engines are needed to use it. The latter gas is being used more in Europe than in this country, but it will come more and more into use as other fuel becomes more expensive.

NATURAL GAS VALUES.

Locality.	B. T. U. Per Cubic Foot.	Authority.
Indiana, average of all	1,023	H. Poole, "Calorific Power of Fuels."
Ohio, " " "	1,030	
Average of all American	975	
American	1,000	Reichelm in "Kent's Handbook."
Burn's Well, Pa.	1,151	McGruder, *Power*, Feb., 1901.
4 Indiana, 3 Ohio, average	1,103	Webster, *Cass. Mag.*, 13–293.
American	1,000	Kerr, " " 18–425.
"	1,100	Taylor, A.I.M.E., 18–859.
Leechburg, Pa.	1,051	Robert's "Gas-engine Handbook."
Pittsburg, Pa.	892	
Average of all	1,033	

COAL GAS.

Strength.		
20 candle-power	675	Reichelm, "Kent's Handbook."
	675	*Elect. Eng.*, Jan. 25, 1901.
15 " "	620	*Power*, Feb., 1900.
Ordinary	550	Donkin, *Eng. Mag.*, Dec., 1900.
"	735	Webster, *Cass. Mag.*, 13–293.
"	735	Taylor, A.I.M.E., 18–293.
28 candle-power	950	Robert's, "Gas-engine Handbook."
19 " "	800	
15 " "	620	
Average of all	706	

WATER GAS.

Kind, Composition.	B. T. U. Per Cubic Foot.	Authority.
From coke	313	Reichelm.
" bituminous coal	377	
Lowe process, H-35 : CO-25 : CH-19	740	Poole, "Calorific Power of Fuel."
" " " 42 " 35 " 12	490	Power carburetted.
" " " 38 " 31 " 17	590	
Granger " " 53 " 36 " 2	283	" uncarburetted.
" " " 30 " 29 " 24	640	" carburetted.
" " " 52 " 12 " 8	331	" from coke.
New York, carburetted	721	Lowe (Kent).
Uncarburetted	322	Webster, *Cass. Mag.*, 13–293.
Carburetted	700	
" H-30 : CO-29 : CH-24	641	Jacobus, A.I.M.E., 17–300.
Uncarburetted	283	
"	322	Taylor, " 18–859.
New York, carburetted	711	Roberts.
Average of the carburetted	651	
" " " uncarburetted	319	

The carburetted gas has oil mixed with it so that it can be used for illuminating purposes, otherwise the flame is not luminous enough unless it is used in Welsbach burners. The heating value is also almost doubled and the additional expense is merely nominal, apart from the cost of the oil used.

[*To be concluded.*]

A NOTABLE BALLOON VOYAGE.

Messrs. Berson and Suehring, the famous meteorological aëronauts of the Berlin Observatory, according to the *Scientific American*, accomplished a magnificent ballooning feat recently by attaining an altitude of 33,800 feet—almost six and one-half miles. This is the greatest height recorded by the instruments carried by the aëronauts, but it is probable that they ascended to a greater altitude. The maximum height they attained, however, is unknown, since both the observers fainted owing to the rarefied atmosphere. The temperature last observed by them was 40° of cold. Herr Berson ascended to 27,000 feet at the Crystal Palace a few years ago. The latest achievement is certainly notable in the annals of aëronautics, but it is not the highest altitude that has been attained by a balloonist. In September, 1862, Messrs. Glaisher and Coxwell ascended from Wolverhampton to a height of 36,000 or 37,000 feet. The exact altitude was not recorded, since the two men were overcome by the intense cold, and the rarefaction of the atmosphere. Mr. Glaisher fainted and Mr. Coxwell only just succeeded in opening the valve by pulling the valve-rope of the balloon with his teeth to enable the vessel to descend.

POTASSIUM SALTS FROM FELDSPAR.

Scientific American gives the following abstract of a process devised by Mr. J. G. Rhodin, of Manchester, England, of manufacturing potassium salts from feldspar. The feldspar is primarily finely ground, and is then mixed with slaked lime and sodium chloride, the mixture being subsequently heated to 900° C. By this means about 85 per cent. of the potassium in the feldspar is extracted in the form of potassium chloride. It is stated that the process is very cheap and is well adapted for commercial purposes. It is proposed to carry out a series of further experiments with the process prior to erecting a factory in Sweden for the manufacture of potassium salts upon an extensive scale. The latter country is peculiarly adapted as the center of such an industry owing to the abundance of feldspar which is to be found there, and for which so far there has been no commercial utility. Another prominent feature of the process is that the insoluble residue that remains after the potassium and sodium salts have been extracted by water constitutes an excellent material for glass manufacture by the addition of a little sand and alkali.

Section of Photography and Microscopy.

Stated Meeting, held Thursday, October 3, 1901.

APPLICATION OF PHOTOGRAPHY TO LEGAL RECORDS.

BY HENRY LEFFMANN.
Member of the Section.

The transfer of real estate under which term (disregarding legal hair-splitting) we may understand land and the buildings thereon, has always been a matter of some difficulty and complexity. In many times and places land was and is practically inalienable. Even now, in the most enlightened nations, the legal fiction is that all land belongs to the supreme authority, that is, the crown in such a country as England, and the State in such a country as our own. Upon this principle rests the right of eminent domain which the State sometimes exercises in its own interests and sometimes confers upon corporations. Land being irremovable, the occupancy of it is not evidence of ownership, and it is impossible to conceal its existence. As it is the only natural monopoly it is the foundation of all wealth in the strict sense of that word. If we carefully analyze the transactions of both nations and individuals, we will find that a common impulse of humanity is that of land-grabbing, whether it be the conquests of a Joshua or Cæsar, or the "benevolent assimilations" of our own age and country.

The enlightened nations of the present day differ considerably as to the amount of land transfer and the methods of it. We are so accustomed in this country, and especially in this city, to the public record of deeds, mortgages and judgments and to the publication of names of sellers and buyers, and even of delinquents, that we are surprised to learn that this is not by any means universal, and in some places quite against the will of the community. Some

notable contrasts are to be found also among what are considered happy countries, in regard to the distribution of land ownership. Thus it is stated on good authority that the average number of land transfers annually in France is about 800,000, while the total number of land owners in England is only about 200,000, so that for England to have as much conveyancing business as France would require that each English owner should make transfers four times each year.

In Philadelphia the exact extent of the business is not easily obtainable, but by inquiry at the office of the Recorder of Deeds I learn that in the record work about 400 books are filled each year, each book containing 560 pages of the size of the large counting-house ledgers. This will make nearly 250,000 pages per year. These books contain principally deeds and mortgages, about equal number of each; releases, powers of attorney and some other documents affecting property make up the remainder. To make these copies, which are expected to be word for word, a large force of transcribing clerks is maintained.

Mr. J. W. Ridpath kindly ascertained for me the statistics of two of the adjoining counties for 1900, as follows:

Montgomery County, 5,548 documents, 12,000 to 14,000 pages.

Bucks County, 2,684 documents, 5,210 pages.

Another very important record department is that of the Register of Wills. In this city, and I believe, generally, it is the rule to preserve the original document and furnish to interested parties a certified copy. The original may be seen by any one. These methods are obviously open to the same objections that apply to the transcription of deeds and mortgages, with the additional one that as the original is open to inspection it may be liable to injury. The number of wills registered in Philadelphia in a year is considerable. A lawyer of this city told me that a will was filed not long ago in a city of western Pennsylvania, of which three official copies were furnished by the register's office, and all the copies differed, although all were duly certified as exact.

It must be apparent to every one that transcriptions by hand are at best clumsy. The Philadelphia departments are in good repute with attorneys, but even under the most favorable circumstances there is considerable delay in the recording of an instrument. This does not operate to the disadvantage of parties, since the instrument takes effect at the moment it is presented for record. The possibilities of error in transcription must always be in mind, although here, again, there is less risk, because the original document is returned to its owner and this document is, of course, always the best evidence.

Some countries have adopted a plan by which the original document is deposited at the registry office; but this method is in vogue to only a limited extent, and even it is not free from objection.

When the systems of transcription were inaugurated, the possibilities of photography were not only unknown, but were quite unsuspected. At the present day the art of duplication of writing or drawing has been brought to high degree of perfection. Several methods are known by which such reproduction can be accomplished rapidly, accurately, and cheaply. Nor is the work confined to the copying of well-made originals consisting of black lines on a white ground; even old yellow manuscripts on parchment can be reproduced with vividness not appreciably inferior to the originals. As some of those present will remember, I exhibited at a former meeting a fine sample of this class. Lead-pencil writing on common white paper can be well reproduced.

Briefly, I propose that for all documents which are to be copied for record a negative shall be made either of full size or somewhat reduced, if thought permissible, and from the negative prints shall be made by the best processes. The negatives are not to be kept, hence the same glass can be used a number of times. The paper must be of the best quality, especially as to its resistance to decay. There is nothing in the problem that is uncertain or indefinite. Photography of this character can be carried out independently of the weather or time of day; permanent pictures

can be made and control can be exercised over the work at all points. With regard to wills, I propose that even if it be thought necessary to keep the original document the public should be allowed access only to the photographic copies, which should be bound in indexed volumes. To facilitate the work some method of drawing up legal documents may be laid down, such as standard size of sheet, character of ink, and other details; but I am informed by an attorney that recording officers would, under present laws and customs, probably be obliged to accept for record any legible document, so that very close requirements would probably be impracticable at first, and as far as wills are concerned, of course impossible. However, whatever the eyes can read, the camera can also read, and there will be no practical difficulty on this point.

Mr. Getty, of the International Engraving Company, has kindly made a full-size copy from a mortgage loaned me by an attorney of this city. The original is about thirteen years old, and hence presents some greater difficulty than a fresh document; but, as will be seen, the result leaves nothing to be desired. In fact, the attorney who loaned the document mistook the copy for the original.

NEW YORK RAPID-TRANSIT SUBWAY.

Work is progressing on the great rapid-transit subway in New York at a most satisfactory rate. Despite the great obstacles presented by the extremely difficult character of the excavation, the street traffic, which must be interrupted as little as possible, and the presence of a multitude of large and small street pipes in the exact route to be traversed, the work of building the tunnel is being prosecuted with a speed hardly to be expected. In the meantime a site for the great power house has been selected and contracts have been closed for boilers, engines and electrical generating apparatus. The electrical part of the power-house equipment was ordered only a few days ago. New York hesitated a long time before deciding to go in for a rapid-transit subway; the project dragged along for years with all sorts of changes in the laws and commissions having to do with the subject; but since the final adoption of the plans and the awarding of the blanket contract, the work has been pushed with a vim and energy that is most commendable.—*Western Electrician.*

GENERAL ELECTRIC COMPANY'S CONSTANT CURRENT TRANSFORMER FOR ALTERNATING SERIES ARC LIGHTING.

[*Being the report of the Franklin Institute, through its Committee on Science and the Arts, on the invention of Prof. Elihu Thomson. Sub-Committee: Francis Head, Chairman; Geo. A. Hoadley, T. C. Smith, Thos. Spencer.*]

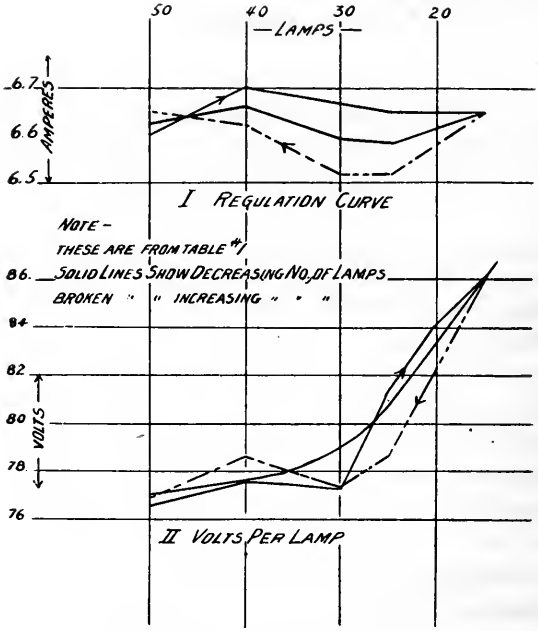
HALL OF THE FRANKLIN INSTITUTE,
[No. 2141.] PHILADELPHIA, January 2, 1901.

The Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts, acting through its Committee on Science and the Arts, investigating the merits of the General Electric Company's Constant Current Transformer for Alternating Series Arc Lighting, reports as follows:

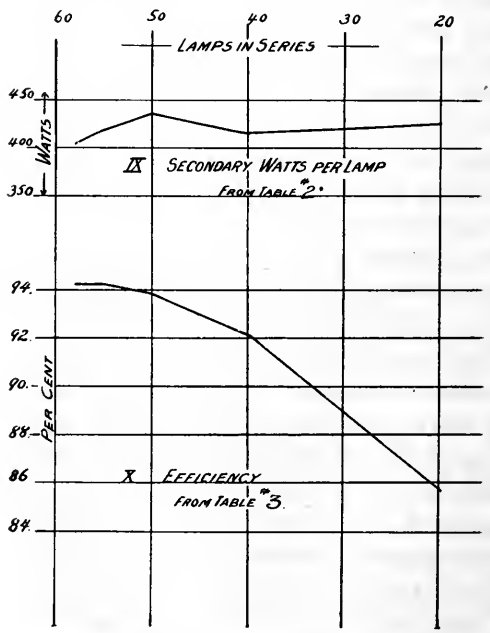
This type of transformer is intended to have its primary connected to an A.C. circuit of constant potential and to deliver from its secondary a current of uniform ampèrage but of varying potential. These transformers are regularly made to take their supply from commercial circuits of 1,100 or 2,200 volts, and to deliver a constant current of 6·6 ampères under a varying potential up to 6,000 volts, depending on the size of the transformer.

They are made in sizes for running twenty-five, fifty, seventy-five and 100 light circuits, with a liberal allowance for circuit drop. One of these sizes is shown in *Fig. 1*.

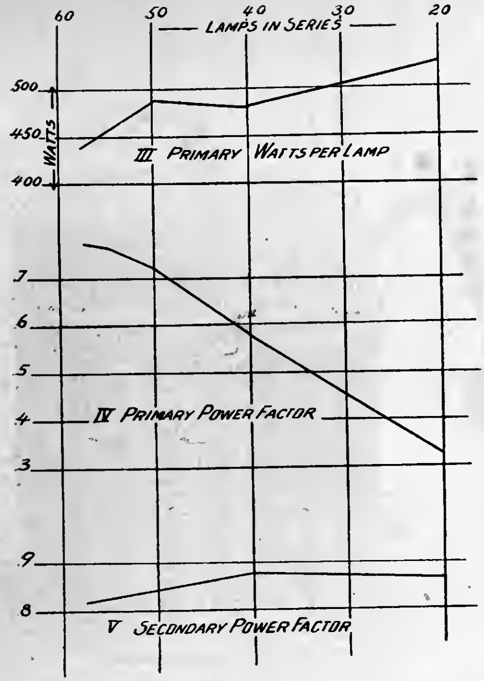
The mechanism of a 25-light machine is shown in *Fig. 2*. In this machine it will be noticed that the bottom coil is fixed, while the top coil is suspended from the end of a lever, and is balanced by an adjustable weight on the outside of the transformer. The bottom coil is the primary and the movable coil is the secondary, and the connections to it are made by the flexible wires at the corner. Surrounding the coils and going through the center is the iron core made of stampings, and held in place by the frame-work of rods and plates. When the transformer is in use, the case is filled



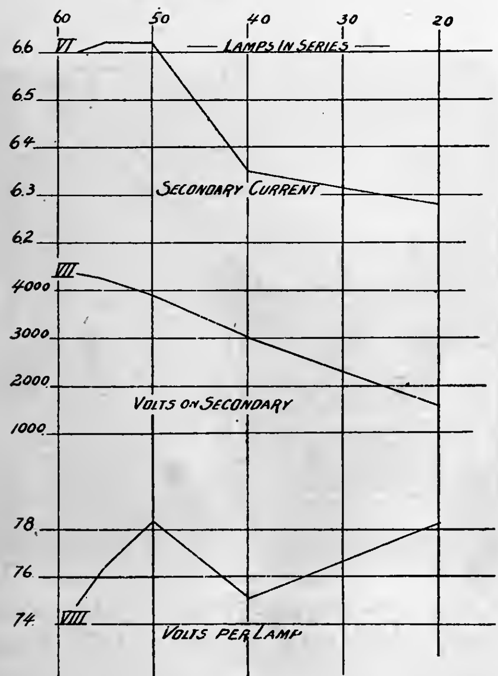
Adjustment for constant current.



Adjustment for constant Watts per lamp.



Adju tment for constant Watts per lamp from Table No. 2



Adjustment for constant Watts per lamp from Table No. 2.

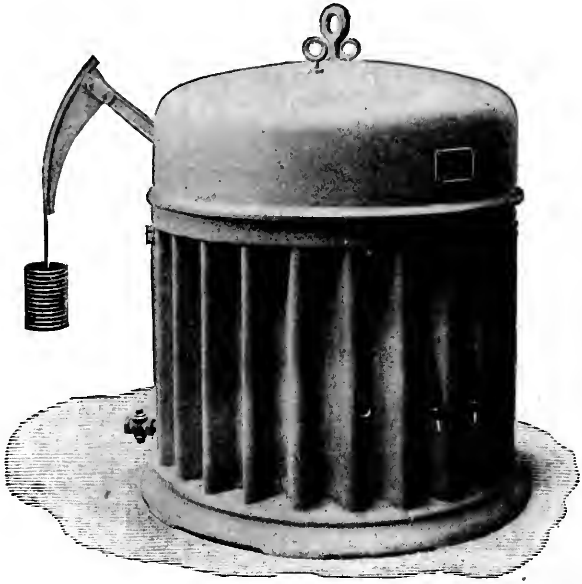


FIG. 1.

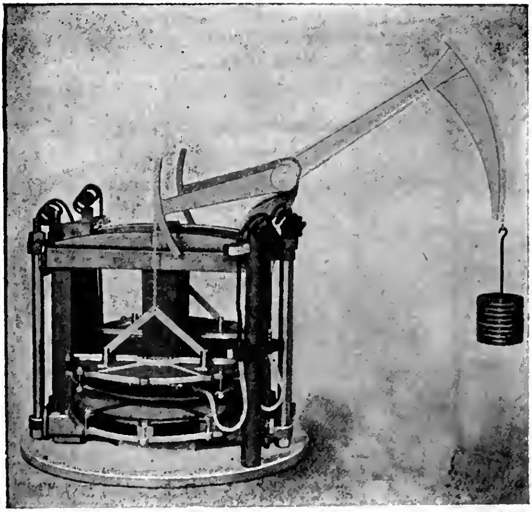


FIG. 2.

with transil oil, which assists in steadying the motion of the movable coil, as well as in cooling the transformer. *Fig. 3* shows the connections to the primary and secondary, and

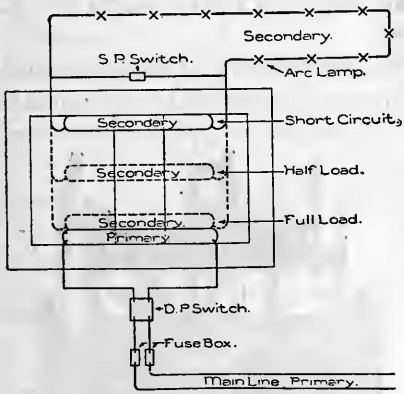


FIG. 3.

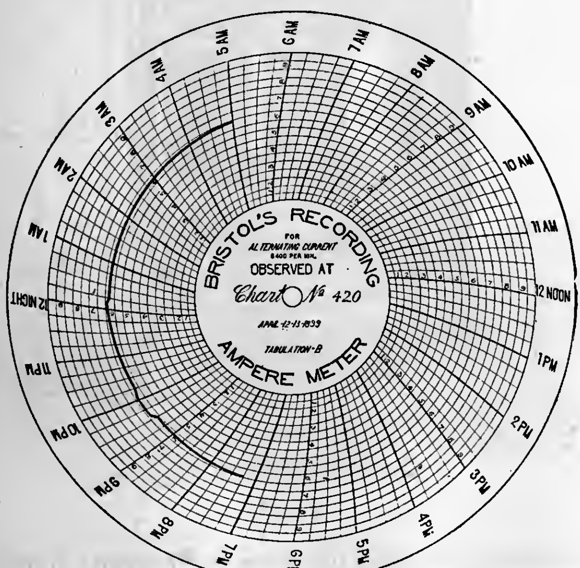


FIG. 4.

the positions of the movable coil at varying loads. When the secondary approaches the primary, the secondary embraces more of the lines of force which are set up by the

primary, and so the E.M.F. of the secondary circuit is increased. When the secondary is moved away from the primary there is more leakage of lines of force and fewer of them cut the secondary, thus reducing the E.M.F. applied to the lamp circuit.

The effect on the primary of this great leakage of lines of force is the same as though there was an external impedance

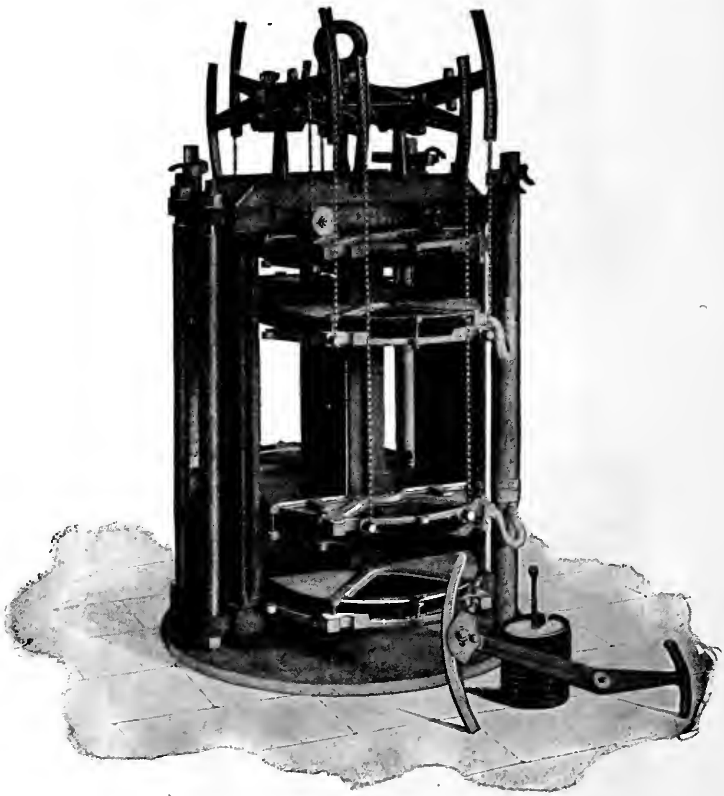


FIG. 5.

in the circuit, so that the primary current remains constant, but with increased angle of lag as the load becomes lighter.

With a change in the external circuit, the secondary, acting under the influence of the repulsion of the primary and the lifting action of the lever, assumes a new position of

equilibrium. By changing the weight on the lever the average current can be varied, while by tilting the sector on the end of the lever, and thus changing its effective length, the strength of the current can be varied throughout the range of the machine.

The mechanism of a 50-light transformer is shown in *Fig. 5*, and its connections are shown in *Fig. 6*. These larger sizes have two sets of primaries and secondaries, which may

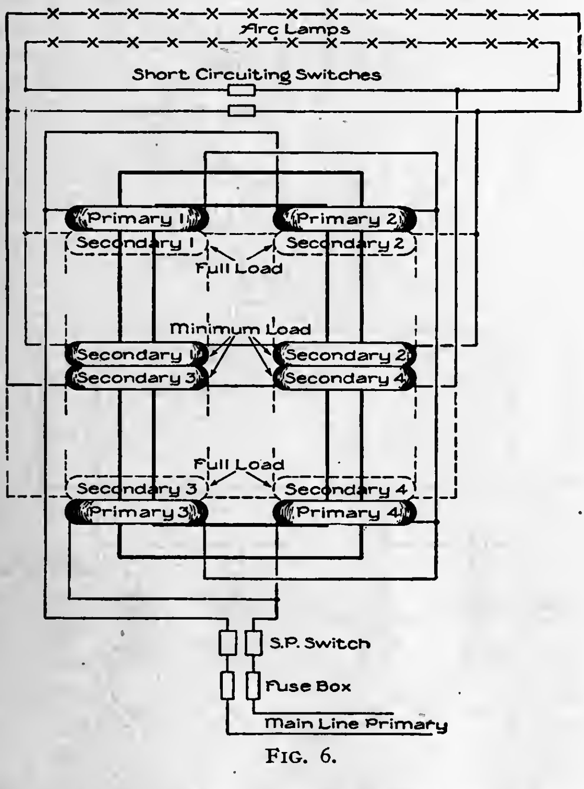


FIG. 6.

be connected in series or parallel, thus taking all the lamps in one or two circuits as desired. To cause the two secondaries to move at the same time, they are joined by the equalizing chain *A*. With this type the effect of the weight is to cause the secondaries to approach the primaries, so increasing the weight increases the current.

With the smaller size the effect of a change of weight is reversed.

Fig. 7 shows the complete connections for a transformer with its secondaries arranged to feed the same circuit.

Fig. 8 shows the secondaries feeding separate circuits.

Fig. 4 shows a record chart taken at Hartford, of an all-night run, which shows the variation in the strength of current.

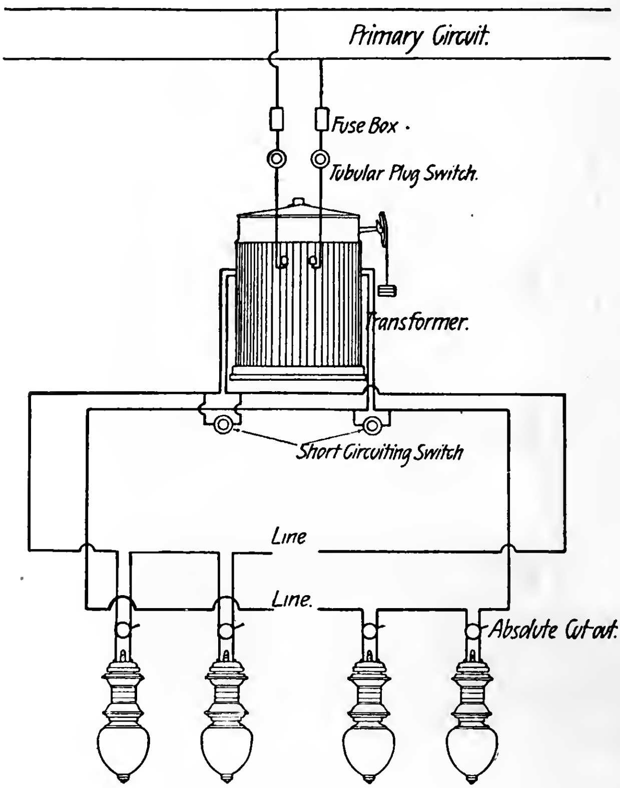


FIG. 7.

The following data were obtained from tests on a 50-light 60-cycle, 6·6 ampère transformer, at the General Electric Company's works, in the presence of a member of the sub-committee.

TEST ON 50 LIGHT CONSTANT CURRENT TRANSFORMER, 6·6 AMPERES—60 CYCLES—CORRECTED READINGS—ADJUSTMENT FOR CONSTANT CURRENT—NO. 1.

Primary Volts.	Secondary. Volts.	Secondary. Ampérés.	Number of Lamps.	Volts per Lamp.
2,200	3,830	6·6	50	76·6
2,200	3,105	6·7	40	77·6
2,200	2,315	6·67	30	77·2
2,200	2,035	6·65	25	81·4
2,200	1,685	6·65	20	84·2
2,200	1,290	6·65	15	86
2,200	1,965	6·52	25	78·6
2,200	2,315	6·52	30	77·3
2,202	3,145	6·62	40	78·6
2,202	3,845	6·65	50	76·9

50 LIGHT CONSTANT CURRENT TRANSFORMER—CORRECTED READING WITH ADJUSTMENT FOR—CONSTANT WATTS PER LAMP—NO. 2.

Primary.					Secondary.							
Volts.	Amp.	Watts.	V × A.	Power Factor.	Volts.	Amp.	Watts.	V × A.	P. F.	Volts per Lamp.	Watts per Lamp.	No. of Lamps.
		529										
2,200	14·78	10,580	32,500	·326	1,565	6·28	8,525	9,828	·867	78·2	426	20
		470										
2,210	14·81	18,800	32,730	·575	3,000	6·35	16,650	19,050	·874	75	416	40
		487										
2,200	14·83	23,500	32,630	·720	3,915	6·62	21,800	25,917	·841	78·3	436	50
		454										
2,200	14·83	25,000	32,630	·766	4,205	6·62	23,050	27,837	·828	76·4	419	55
		434										
2,200	14·82	25,200	32,600	·773	4,335	6·6	23,350	28,600	·816	74·7	403	58
	14·8175										420	

Figures in bold type—primary watts per lamp.

EFFICIENCY. NO. 3.

CALCULATED FROM OUTPUT AND TOTAL LOSSES.

Load.	Watts Output Measured.	Total Losses + Core Losses.	Input = Output + Losses.	Efficiency. Per Cent.
58 lamps	23,350	1,426	24,776	94·24
55 "	23,050	"	24,476	94·17
50 "	21,800	"	23,226	93·87
40 "	16,650	"	18,076	92·11
20 "	8,525	"	9,951	85·67

50 LIGHT CONSTANT CURRENT TRANSFORMER.
CORRECTED READINGS.

COPPER LOSSES—NO. 5.

Primary.			Secondary.		
Volts.	Amperes.	Ohms.	Volts.	Amperes.	Ohms.
20	12·88		55·6	6·6	
19·9	12·86		55·7	6·6	
19·8	12 85		55·6	6.61	
19·75	12·82		55·4	6 6	
19.86	12·85	1 545	55·57	6·602	8·42

CORE LOSS—NO. 4.

	Primary.	
Volts.	Amperes.	Watts.
2,200	·439	720

The above was taken at 33° C.
Oil temperature reduced to 25° C. Primary resist. 1·495 ohms. Secondary resist. ·815 ohms.
C R 330 and 354.

$$\text{Total losses at } 33^\circ \text{ C.} = \begin{cases} \text{Core loss} & = 720 \\ C^2R_P = 1{\cdot}545 \times 14{\cdot}82^2 & = 339{\cdot}3 \\ C^2R_S = 8{\cdot}42 \times 6{\cdot}6^2 & = \underline{366{\cdot}7} \\ & 1426 \end{cases}$$

IMPEDANCE TESTS—NO. 6.

Coils Apart.			Coils Together.		
Primary.		Secondary.	Primary.		Secondary.
Volts.	Amperes.	Amperes.	Volts.	Amperes.	Amperes.
2,040	14·76	6·6	326	14·52	6·6

These tests were made on a transformer which had been in commercial service some months. Current was supplied from an alternator driven by a D.C. motor, which by field regulation allowed the current to be kept at 60 cycles.

An inspection of curve I shows the regulating power of the transformer, when set to give constant current, the greatest variation being 1·5 per cent. from the normal.

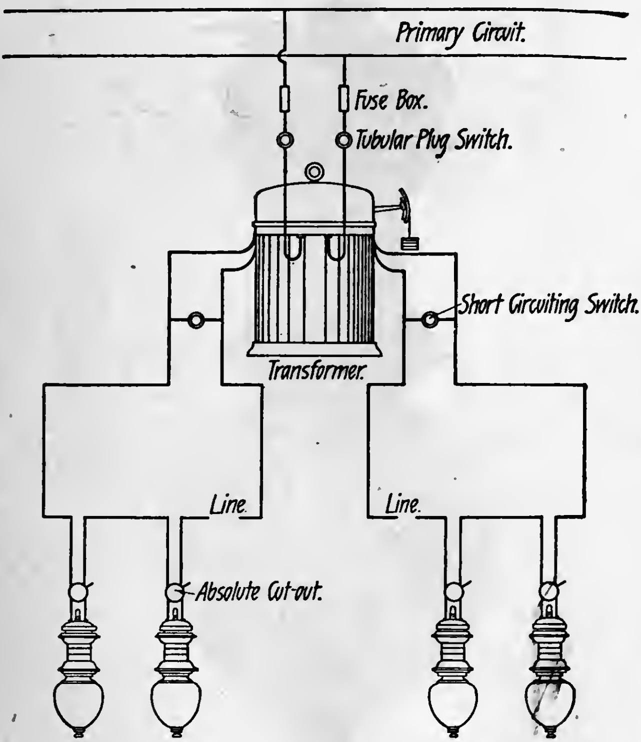


FIG. 8.

Curve II shows rather an interesting phenomenon, namely, that the voltage and watts per lamp increased as the number of lamps was reduced.

This action has caused the makers to adjust the transformers so as to give approximately constant watts per lamp, as in curve IX. This has the effect of reducing the current as shown in VI.

This rise in voltage with light loads was explained by the alteration in the current wave form, the curve becoming less peaked and more in the shape of a sinusoid.

The primary power factor, curve IV, points clearly to the fact that these transformers should be so selected as to work nearly full load.

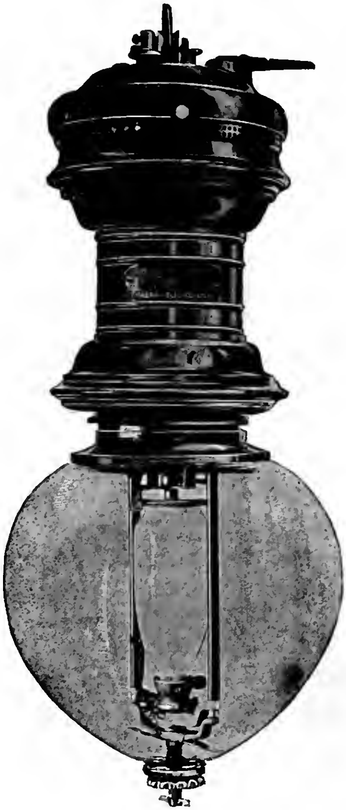


FIG. 9.

The efficiency at full load is fair, and holds up well to two-thirds full load.

A station distributing at commercial constant potential voltage, say 1,100 or 2,200, could, by using a self-adjusting reactive coil, operate circuits of thirteen or twenty-six lamps, depending on the station. To operate commercial

circuits of fifty or more lamps, additional step-up transformers would be necessary.

In considering the efficiency of a constant current transformer, we should not then simply make comparison with

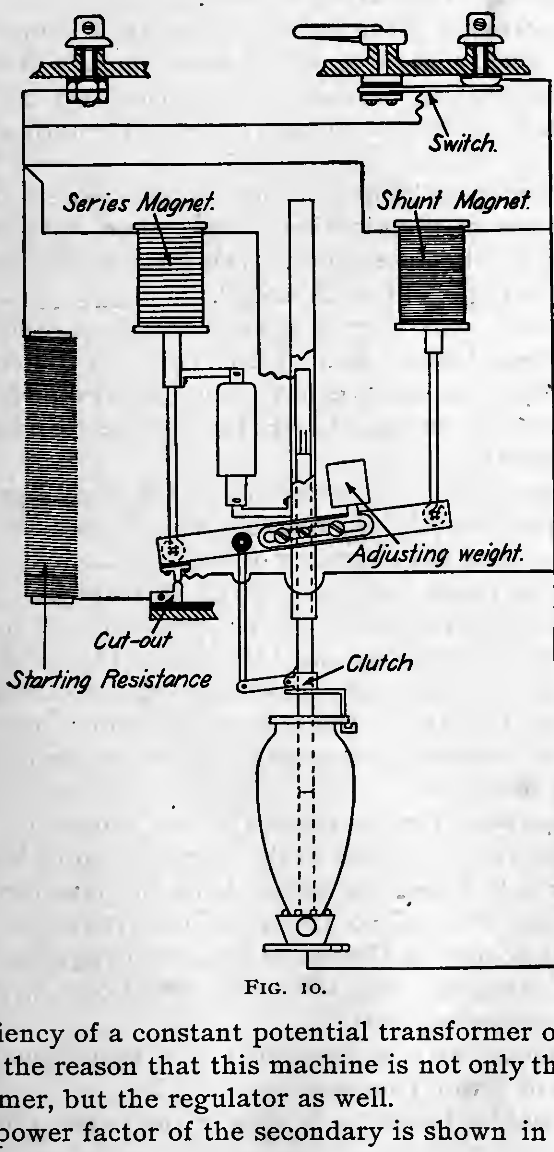


FIG. 10.

the efficiency of a constant potential transformer of similar size, for the reason that this machine is not only the step-up transformer, but the regulator as well.

The power factor of the secondary is shown in V. The

lamps used on this circuit were the G.E. enclosed arc form 3. This lamp, its mechanism and diagram of connections is shown in *Figs. 9* and *10*. It is a differential lamp and those in use were free from the usual humming sound so noticeable with alternating arc lamps.

A general idea of the light given by these lamps can be had from *Fig. 11*, showing illuminating curves from a six ampère alternating current lamp, a 6·6 direct current enclosed lamp and the ordinary 9·6 open alternating current lamp.

The six ampère lamp gives less candle power, but gives a better form of illumination curve, when used on poles 25 feet high as in street work. The curve from the 6·6 lamp would lie between curves A and D.

In several towns where a member of the sub-committee has seen these lamps operated from constant current transformers, there has been a noticeable improvement in the uniformity of illumination, over the intense contrasts made by the open arc.

Correspondence with owners of plants using this system has brought universally favorable replies, both as to the operation and to the character of the lighting.

Referring to the patents covering this subject, we find that the original patent No. 363,186, granted to Elihu Thomson on May 17, 1887, contained the germ of the idea.

From the illustrations contained in this specification, it will be seen that this is the now familiar effect of repulsion between an alternating magnetic field and a conductor subject to its influence.

This has been farther elaborated, as shown in patents No. 516,846 and 7, granted to the same inventor, March 20, 1894, in which is seen the principle of the transformer as it is now made. Patents No. 428,648, granted the same inventor May 27, 1890, refer to the use of ribs, or corrugations, on the case containing the coils, and to filling the case with oil to assist in dissipating heat.

From the above it appears that this transformer is the invention of Elihu Thomson.

The Franklin Institute, in view of the importance of the

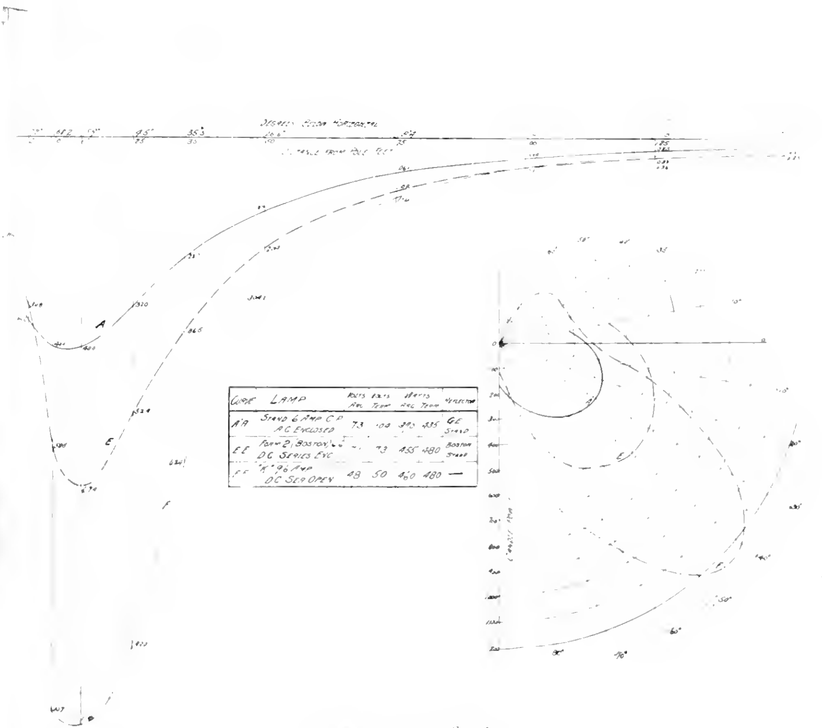


FIG. 21.—ILLUMINATING CURVES.

invention, providing as it does such an excellent method of operating series arc lamps from the same generators which supply incandescent light and power, recommends to Elihu Thomson the award of the John Scott Legacy Premium and Medal, for his invention of the Constant Current Alternating Arc Light Transformer.

Adopted at the stated meeting of the Committee on Science and the Arts, held Wednesday, February 6, 1901.

JOHN BIRKINBINE, *President.*
WM. H. WAHL, *Secretary.*

Countersigned by
LOUIS E. LEVY,
Chairman Committee on Science and the Arts.

A GREAT ACHIEVEMENT IN ENGINEERING.

The near completion of the new Delaware Breakwater, below Philadelphia, has been the occasion of a noteworthy statement from General Gillespie, chief of the Corps of Engineers of the United States Army, which we find in the columns of the Philadelphia *Public Ledger* of August 29th, and the substance of which we here condense.

The old Delaware Breakwater is about one mile long, contains 1,231,587 tons of stone, was seventy years (1828 to 1898) under construction, cost about $2,807,000, and created a limited and shallow harbor of refuge, now used by small coasting and fishing vessels. In building it the greatest amount of stone deposited in any one year was about 32,000 tons.

The new breakwater, designed in 1892, is about 1·5 miles long, covers an area of 552 acres, with minimum low-water depth of 30 feet, besides 237 acres with 24 feet depth; contains 1,464,410 tons of stone, which have been placed in position in forty-four working months, the average per month being 32,300 tons, the maximum per month 62,719 tons, and the maximum year's work 450,460 tons. The work has thus been done about twenty-five times as rapidly as that of the old breakwater. As to its cost, a direct comparison based upon its length would not be fair. A better measurement is found in the circumstance that in 1892 a commission of engineers, basing its calculations upon the experience gained in the building of the old breakwater, estimated the probable cost of the new one at $4,665,000; whereas, it will be fully completed in November next at a cost of about $2,239,334, or slightly less than half the estimate.

This surprising result has been partly due to the very low price ($1.18¾) per ton at which, by the use of powerful machinery at both breakwater and quarry, the contractors have been able to put the rock in place; but it is also largely the result of the great saving of at least 500,000 tons in the amount of stone required, which has been effected by the new method of construction employed. Without going into a detailed description of this method, we may

say that it consists essentially in adopting for the submerged portion of the breakwater a cross-section determined by the action of the sea itself, instead of a much flatter slope, such as was previously supposed (without experimental reason) to be necessary. Lieutenant-Colonel Charles W. Raymond, the engineer in charge, is entitled to the credit of having proposed this bold innovation, secured for it, by his arguments and experimental proofs, the approval of the Board of United States Engineers, and supervised its execution with vigilance and intelligence. In the words of General Gillespie the work is "a monument to his efficiency and skill as an engineer."

During the progress of its construction the new Delaware Breakwater has been visited by many engineers and has been watched with great interest, as certain, if successful, to mark a memorable advance in the methods of harbor engineering. Thus far the minutest observations have failed to detect the least sign of weakness or inadequacy in the novel submarine section employed. For the local conditions there is no doubt that the plan is successful. Whether it can be employed, and how it would have to be modified for other localities and conditions remains to be determined. The theory of it—namely, that in any locality the sea itself should be allowed to determine the submerged section for a breakwater, or, in other words, that the talus of the broken stone should be that which the sea has been found to form, and thereafter not to disturb—seems to be universally applicable. At all events, no great structures of this class will be undertaken hereafter in the civilized world without careful consideration of this new American precedent.—*Engineering and Mining Journal.*

RIVER PROFILES.

An interesting and valuable publication of the Department of Hydrography of the United States Geological Survey on the "Profiles of Rivers in the United States," by Henry Gannet, has just been published, and is now available for distribution. It embodies within 100 pages the leading facts of about 150 of the most important rivers and streams of the country, noting their length, drainage area, the location of water power in their course, their peculiarities of flow and the nature of their drainage basins.

The rivers selected are those which are the largest in size and bear most directly upon the varied interests of the country, such as the Connecticut, Hudson, Susquehanna, Ohio, Potomac, Mississippi, Missouri, Platte, Colorado, Sacramento, Columbia and others. The figures for the tables showing height above sea level and fall per mile were collected from various sources. Some were obtained from the reports of the Chief Engineer of the United States Army, some from railroad companies when their lines cross the stream, and some from the atlas sheets of the United States Geological Survey.

In the case of such rivers as the Connecticut, Susquehanna, Mississippi and Colorado, where the surrounding country is in part or whole of peculiar physiographic interest, very excellent and vivid descriptions of its leading physical characteristics are given, which add to the interest and render it valuable from an educational standpoint in geographic and physiographic instruction.

The pamphlet is the result of much careful work, and is the first attempt to collect and compile this information in its present form. W.

THE DIESEL MOTOR.

[Being the report of the Franklin Institute, through its Committee on Science and the Arts, on the Invention af Rudolf Diesel, of Munich, Bavaria.]

HALL OF THE FRANKLIN INSTITUTE,
[No. 2016.] PHILADELPHIA, March 23, 1901.

The Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts, acting through its Committee on Science and the Arts, investigating the merits of the Diesel Motor, reports as follows:

The Diesel Motor is an improved motor of the class known as "internal combustion" engines, and therefore, before beginning an examination of its claims to novelty and award, a brief review of the principles of such motors may be appropriate.

Practically all modern internal combustion motors, including the Diesel, operate upon a cycle first enunciated by Beau de Rochas in 1862, in which the combustible, either gas or hydro-carbon vapor, is introduced in one stroke, compressed in the next, ignited and burned in the third, and exhausted in the fourth, there being but one power stroke in every four.

The principal feature in all engines of this class has been the compression of the charge, it having been found that by using the momentum of the flywheel to compress the charge of mixed combustible and air, a notable economy and ease of working was effected. This principle was first practically utilized by Otto, in 1876, and his engine has been extensively used, both in Europe and America, principally employing illuminating gas as fuel. Various trials have shown for such engines a thermal efficiency decidedly higher than the steam engine, the proportion of heat converted into work ranging from 17 to 22 per cent. in various instances, while in the case of the steam engine and boiler combined 12 per cent. thermal efficiency is considered high,

and has been attained only by large engines under favorable conditions.

In 1897, Herr Rudolf Diesel read a paper before the Verein Deutscher Ingenieure, at their convention at Cassel, describing his studies in internal combustion motors, and his successive attempts to realize his ideas in practice. Herr Diesel began by assuming that the highest efficiency would be realized by the accomplishment of the Carnot cycle, and then proceeded to devise a motor in which, so far as was practicable, this cycle should be produced in actual operation.

The Carnot cycle is formed of two isothermal, and two adiabatic curves, the expansion during the reception of heat being such as to maintain a constant temperature. When the addition of heat ceases the temperature falls in consequence of work done, giving a curve of adiabatic expansion. During the return, heat is withdrawn in proportion to the reduction of volume, and the curve is again isothermal. The compression is adiabatic, and in the pure Carnot cycle the gas has again returned to its original volume.

Mr. Diesel has attempted to realize, within the limitations of practice, this cycle in his engine, and in so doing has produced a motor of very high thermal efficiency. In order to accomplish this result it was evident that a much higher degree of compression was necessary than that used in existing motors, since it was demanded that the charge be compressed adiabatically to the maximum initial pressure at which the motor was to be operated, this pressure not to be exceeded by the gases generated during the combustion. Such a compression would naturally produce an increase in temperature sufficient to ignite the combustible, and hence it became apparent that the fuel must not be introduced with the air but that the air must first be compressed adiabatically and that the fuel must then be introduced and burned during the out-stroke of the piston isothermally, if the desired cycle was to be practically realized.

Here a practical feature of importance appears. In ali existing internal combustion motors, the question of the

ignition of the charge has been one upon which much ingenuity has been expended. In the early Otto engines, a small flame was employed, acting through openings in an ingeniously constructed slide valve; the flame being blown out by each ignition and relighted from a fixed gas burner. This was followed by the invention of the incandescent tube by Daimler, and this again by the use of the electric spark, and at the present time nearly all internal combustion engines use either the hot tube or the spark ignition.

In the Diesel motor, however, the high temperature attained by the compression of the air is sufficient to provide for the ignition of the combustible, and it is only necessary for the fuel to be injected into the heated air for its ignition and combustion to take place.

In this theoretical discussion of the subject, Mr. Diesel laid down four conditions as essential to the realization of the highest economy:

First, that the combustion temperature must be attained not by the combustion, and during the same, but before, and independent of it, by the compression of pure air.

Second, that this is best accomplished by deviating from the pure Carnot cycle to the extent of combining two of the stages of the cycle, and directly compressing the air adiabatically, instead of first isothermally from 2 to 4 atmospheres, and then adiabatically to 30 or 40 fold.

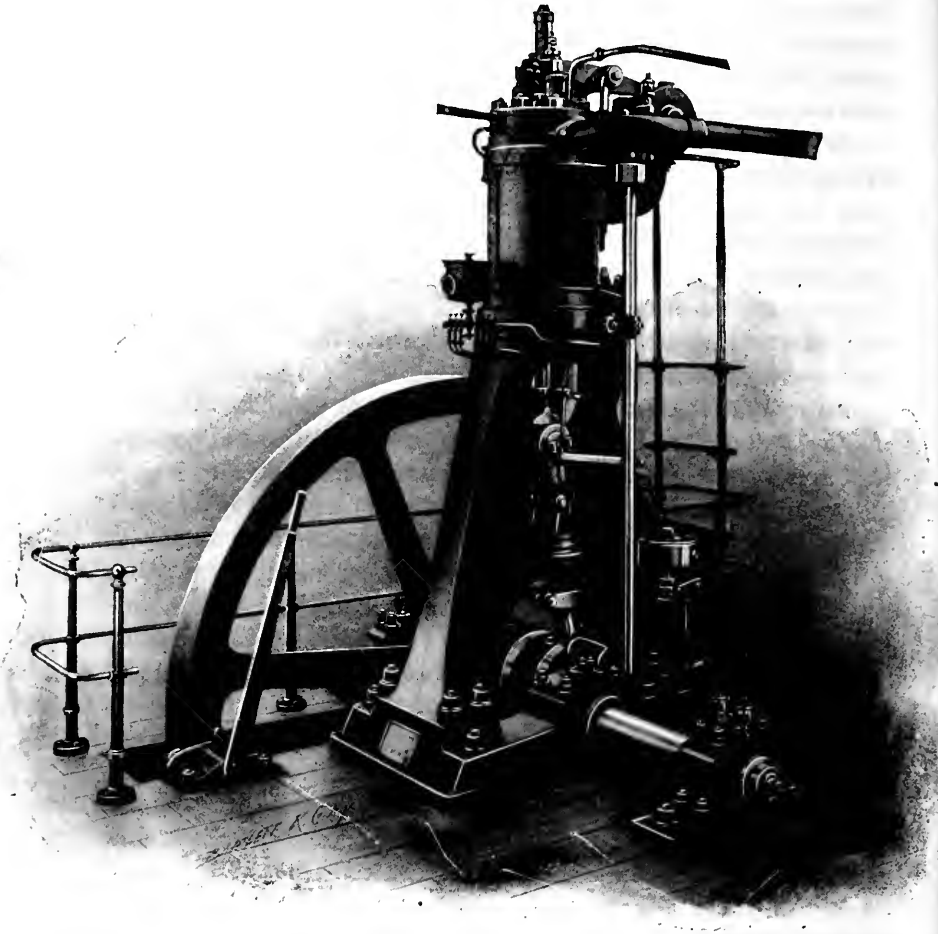
Third, that the fuel be introduced gradually into the compressed air, and burned with little or no increase in temperature during the period of combustion.

Fourth, that a considerable surplus of air be present.

It will be seen from these conditions that a motor to meet them, although operating upon the so-called "four-cycle" principle, must differ essentially from engines of the Otto tpye, and it was to realize these conditions that the Diesel Motor, as presented to the committee, was designed.

The general construction of the 20-horse power motor examined by the committee is seen by reference to the illustrations. It resembles in design a vertical steam engine of the marine type, except that all parts are built to stand the high pressures employed. The working cycle is as follows:

On one down-stroke the main cylinder is completely filled with pure air, the next up-stroke compresses this to about 35 atmospheres, creating a temperature more than sufficient to ignite the fuel. At the beginning of the next down-stroke, the fuel valve opens, and the petroleum, ato-



Twenty horse-power Diesel engine, German type.

mized by passing through a spool of fine wire netting, is injected during a predetermined part of the stroke into this red-hot air, resulting in combustion controlled as to pressure and temperature. This injection is made possible by

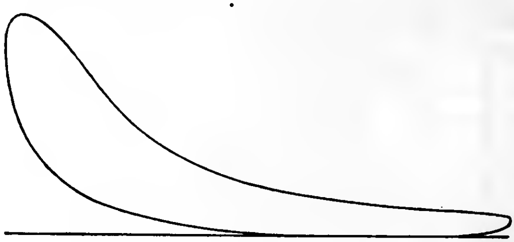
the air in the starting tank, which is kept by the small air-pump at a pressure some 5 or 10 atmospheres greater than that in the main cylinder. A small quantity of this air enters with the fuel charge, which it atomizes as described. When the motor is running at full load, a very small quantity of injected air suffices, and the pressure in the air tank steadily rises. At half load, with less fuel injected, more air passes in. For this reason, the starting tank is made large enough to equalize these differences, and a small safety valve is provided on the air-pump.

The petroleum is pumped into the fuel valve casing by a small oil-pump bolted to the base-plate. This pump is arranged to pump a fixed maximum qnantity of petroleum. A by-pass is provided so that this whole quantity, or any portion of it, can be returned to the supply tank. The governor controls the action of this by-pass valve, closing it just long enough to compel the exact quantity of the fuel required to pass into the fuel valve casing. The full charge of air being always supplied for complete combustion, it matters not whether the governor permits one or fifty drops of petroleum to enter the working cylinder at each motor stroke, the combustion is always complete. To stop the motor it is only necessary to close the valve which admits the petroleum into the fuel valve casing. The valve gear consists of a series of cams placed on a shaft journalled on brackets cast on the cylinder.

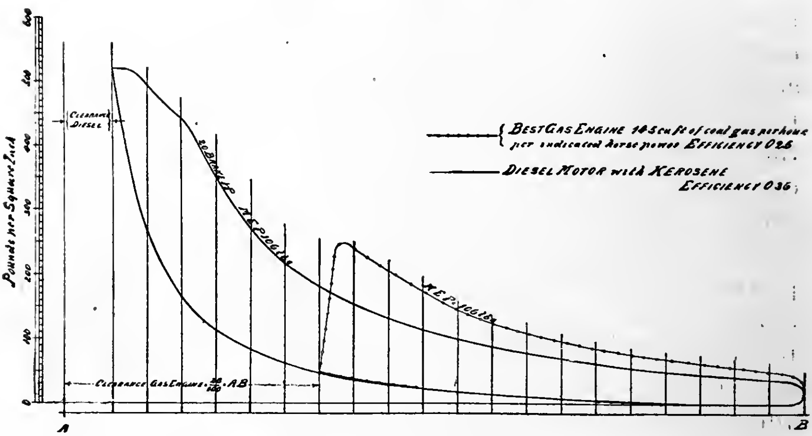
The especial claims covered by the Diesel American patent are in substance: (1) The compressing of the air alone to a point producing a temperature above the igniting point of the fuel to be consumed, and then gradually introducing the fuel for combustion into the compressed air while expanding against a resistance sufficient to prevent an essential increase of temperature and pressure, then discontinuing the supply of fuel and further expanding without transfer of heat; (2) the means in combination with the general details of the motor, for opening the valve and admitting the fuel at the beginning of the stroke, and of cutting it off at a predetermined part of the stroke, *i. e.*, of governing by controlling the duration of the combustion;

(3) of the combination, with the above operations, of a reservoir of compressed air for the purpose of starting the engine and of introducing the fuel.

The extent to which the theoretical results are realized is seen in the indicator diagrams, an example of which is appended. The chairman of your committee has witnessed the operation of the 20 horse-power engine tested in New York City by Professor Denton, and can confirm the fact



Full load, 180 revolutions.



that diagrams similar to the attached were produced from the engine during its operation.

The results of tests of the Diesel motor are very harmonious, although made by several observers at distant points from each other. Thus, the test made in Germany by Professor Schröter showed an indicated thermal efficiency of 34·2 per cent. at full load, and 38·5 per cent. at half load; and an effective thermal efficiency (based on brake horse-power) of

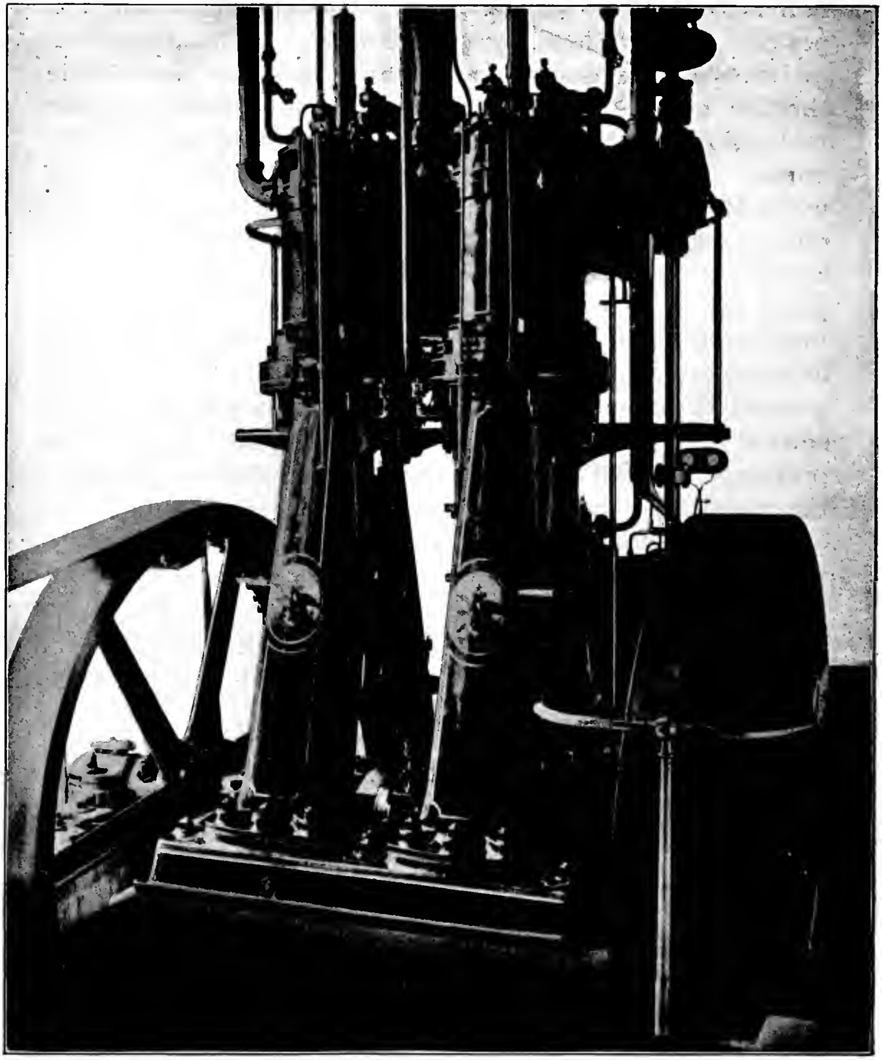
25·7 per cent. at full load and 22·4 per cent. at half load. The tests of Professor Denton in New York showed similar results, *i. e.*, indicated efficiency at full load, 37·2 per cent., at half load, 41·2 per cent.; brake efficiency at full load, 25·06 per cent.; at half load, 19·09 per cent.

It has been a question as to how far these remarkable thermal efficiencies are due to the more or less complete realization of the Carnot cycle in the performance of the motor. That they are partially so is generally conceded, while Herr Diesel himself admits that a portion of the high efficiency is probably due to the completeness of the combustion. There seems to be no doubt that combustion takes place far more readily and completely in air under high pressure than at atmospheric pressure, or even at a pressure of a few atmospheres. In the Diesel motor the air is compressed to about 35 atmospheres, say 500 pounds to the square inch, and at such pressures, with an excess of air present, a sprayed liquid fuel, such as petroleum, appears to be completely burned, leaving no trace of residue. The chairman of your sub-committee was present when the lid was removed from the cylinder of a motor after it had been running almost continuously for several weeks, and there was no trace of deposit to be seen upon the cylinder walls, while the exhaust, when the motor is running, deposits no discoloration upon a sheet of white paper.

That a portion of the high economy is due to the complete combustion in a mass of highly compressed and heated air appears to be true, and this is an essential feature of the motor.

During the summer of 1900 the chairman of your sub-committee had the opportunity of examining and photographing the 75 horse-power motor exhibited by the Augsburg Machine Works at the Paris Exposition at Vincennes, and personally took a number of indicator cards which correspond closely with those which have been published at various times. The exhaust of this engine was entirely free from smoke or visible discharge, and did not soil a handkerchief held within a foot of the end of the exhaust pipe. He also had the opportunity of visiting the works of the

Vereinigte Maschinenfabrik, Augsburg, und Maschinenbaugesellschaft Nürnberg Aktien Genellschaft, at Augsburg, where all the experimental work has been performed,



Sixty horse-power Diesel engine, German type.

and there had the opportunity, under the personal guidance of Herr Diesel, of examining the early models and machines

and the experimental laboratory, where all the investigations have been conducted.

An interesting feature relating to the motor, and one which, in the opinion of your committee, should render it especially suitable for award, is the thoroughly scientific manner in which the whole execution has been worked up from previously-conceived theoretical study. The various thermal cycles were first examined and studied, and that of Carnot was selected as conducing to the maximum thermal efficiency. The modifications in this cycle necessary to enable it to be approximately realized in practice were then studied. The various fuels available were tested, chemically and thermally, the laboratory at Augsburg containing a great number of samples, labelled with the results of chemical analysis, and the record of calorific value as found in the Junker calorimeter. The indicator diagrams obtained from the engines in actual practice agree so closely with those set out to be obtained according to the theoretical investigations, that it is, in the opinion of your committee, a noteworthy example of the true manner in which science and practice should be joined in actual work.

The chairman of your committee had the opportunity of being present, as delegate of the American Society of Mechanical Engineers, at the Mechanical Congress at Paris during the Exposition, and in the discussion of the Diesel Motor which there took place the following points were brought out:

An internal combustion motor should have the following features realized in its action to the greatest possible extent:

(1) There should be as complete a sub-division as possible of the combustible and as thorough a mixture as practicable of it with the air.

(2) The air used in the combustion should be raised to as high a temperature as possible.

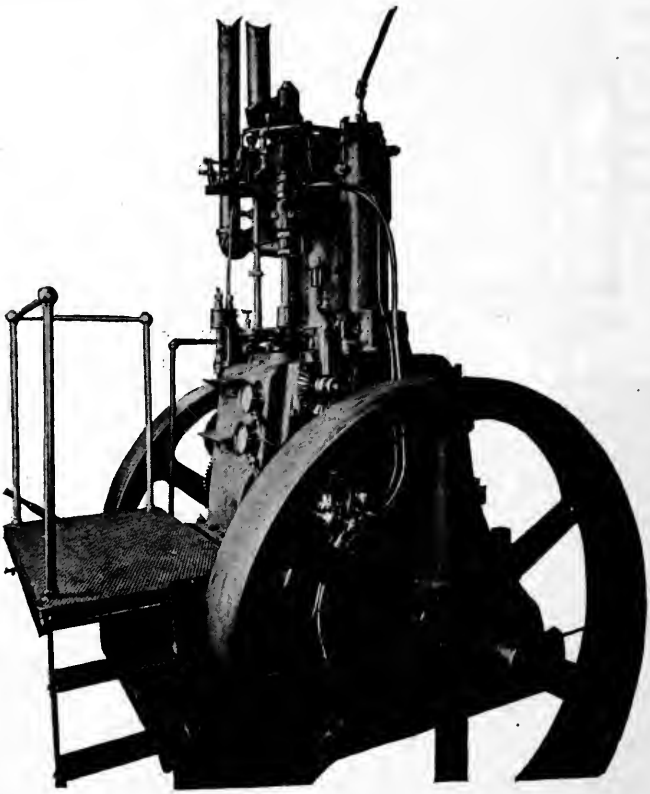
(3) All previous vaporization of the combustible should be avoided, and there should be no separation of it into light and heavy constituents.

(4) Any contact of the combustible with the more or

less cold walls of the combustion chamber should be avoided.

(5) There should be no previous mixture of the combustible with more or less cold air.

(6) The combustion should be, as far as possible, independent of the velocity of propagation of the flame and the uncertainties accompanying it.



Thirty horse-power Diesel engine, American type.

(7) The pressure should be raised as high as possible before the commencement of the combustion.

The extent to which these theoretical features have been attained in the Diesel Motor may be enumerated as follows:

(1) The sub-division of the combustible is secured by delivering it into the combustion chamber through a pul-

verizer employing air under a great excess of pressure; by means of which each particle is surrrounded with fresh air.

(2) The preheating of the air is secured by the previous compression to a degree greater than any attained by the subsequent combustion.

(3) Any previous vaporization or gasification of the combustible is entirely avoided, the fuel being introduced cold, in its normal condition, the pulverization being entirely mechanical.

(4) No contact between the combustible and the cooler walls of the combustion chamber occurs, the fuel being in jected into the midst of the previously compressed air, with which it is completely consumed before it can come in contact with the walls. This is verified by the complete absence of any coating of carbon upon the cylinder walls, even after continuous runs of several months.

(5) There is, in the Diesel Motor, no previous mixture whatever of the combustible with air.

(6) There being no previous admixture of air and combustible, there can be no propagation of flame whatever, each particle burning of its own ignition due to the high temperature of the air with which it is in contact.

(7) The pressure is raised by the compression to a higher degree than is subsequently attained at any point in the stroke by the combustion.

At the Mechanical Congress at Paris, Herr Diesel reported that the latest trials with the motor have realized an indicated thermal efficiency of 40 per cent. under full load and 50 per cent, under half load. At the time when he first began his studies the best indicated thermal efficiency of internal combustion motors was 15 to 18 per cent., and in 1893, when his first publications appeared, the indicated efficiency had risen to 19 to 20 per cent.

At the first attempt the Diesel Motor gave an efficiency of 28 to 30 per cent. thus adding 50 per cent. at once to the best previous results, and this by the scientific application of previously-known principles.

All the members of your committee have not had an opportunity to consider the invention as described from a

commercial point of view, nor do they feel sure that the high thermal effects obtained are fully utilized, as there may be losses through excessive friction between the cylinder and the crank which will neutralize some of the heat gain that is claimed. Apart from this consideration, however, those members of the committee who have not been able to study the machine so thoroughly as the chairman, join in his recommendation as expressed herewith, believing that what Mr. Diesel has done is worthy of the high commendation suggested, from the Franklin Institute.

In view of the facts as above stated, which have been verified by careful personal inspection and study by the chairman of your sub-committee of motors in the United States, France and Germany, and by his exhaustive examination of the stages of the invention in the inventor's study at Munich, and the original mechanical laboratory at Augsburg, the Franklin Institute awards the Elliott Cresson Medal to Rudolf Diesel, of Munich, Bavaria, for his improvements in Internal Combustion Motors, and for his practical application in actual work of the fundamental principles of thermodynamics.

Adopted at the stated meeting of the Committee on Science and the Arts, held Wednesday, May 1, 1901.

JOHN BIRKINBINE, *President.*
WM. H. WAHL, *Secretary.*

Countersigned,

LOUIS E. LEVY,
Chairman Committee on Science and the Arts.

DOUBLE-STAR ASTRONOMY.*

By Prof. Eric Doolittle University of Pennsylvania,
Member of the Institute.

To the early Chaldean astrologers who sought to read from the stars the things which the future had in store for them the appearance of the heavens was almost precisely as we see it to-day. The observer who will go out into the dark country on any starlight evening and watch the "multitude of fires" rise in the east, climb slowly upward and finally disappear in the west, will behold the spectacle which, with awful regularity, has been presented night after night since life on our world began. Even the singular grouping of stars into constellations, in which a far earlier people than the Chaldeans traced out the forms of animals and rivers and such like, has changed but little; the bands of Orion, the Pleiades, and doubtless also the Dragon, the two Bears, the River and the other constellations were as familiar to the observers of Job's day as to us.

It was inevitable that men must from the first have thought sometimes concerning this "glorious host of light," where it came from, where it went to with the rising of the sun, and why, year after year, it did not change its appearance; but it was slowly, indeed, that the true conception of our universe emerged from the fanciful speculations of the ancients. For, in the first place, much of the labor of astronomers was given up to the vain effort to find some connection between the motions of the stars and the affairs of their every-day life, and, in the second place, because the idea of a round world almost infinitely distant from the stars, though so familiar to us, must have been to them an hypothesis almost unthinkable in its absurdity. Between the years 500 B. C. and 400 A. D., however, a great advancement began, particularly in Greece and Arabia. It was during this period that there arose the great Greek philoso-

* Abstract of a lecture delivered in Association Hall on Friday, October 18, 1901.

phers, and the fathers of astronomy, Hipparchus and Ptolemy. To these it was well known that the earth was round, its size had been several times measured, and the motion of all the planets except the earth through the sky was well understood. Then succeeded the darkness of the Middle Ages when all this knowledge was practically lost, until about the year 1600, when the modern revival of scientific thought began.

The labors of Copernicus, Tycho Brahe, Galileo, Kepler and Newton now following in quick succession gave astronomy a marvellously rapid development. Thus, in less than a century, the enormous size of the sun, its true distance and the nature of the motions of the planets about it, were all discovered. But of immensely greater importance than this was the discovery of that law which regulates the motion of the earth and all the other celestial bodies, and by the aid of which the aspect of the heavens at the most remote epochs can be predicted. We shall see, also, that this same law of gravity extends to the very limits of our stellar system and that it alone is a sufficient cause of the evolution of the great double-star systems.

Before proceeding directly to our subject, let us try to get some correct idea of the comparative sizes and positions of the bodies of our universe. And in the first place it may be said that we cannot *conceive* of the magnitudes with which we shall meet. We know that the earth is eight thousand miles in diameter, but it is quite impossible for the mind to comprehend a mass of this size. We may stand looking over the expanse of a great prairie, or of the ocean, and represent to ourselves that, while the surface appears flat, it is not really so; that, at a point one mile away from us, it has curved downward about eight inches, and that if this uniform downward curving be continued for 24,000 times as far, we will have completely rounded the sphere and will approach the same plane behind us. But the magnitude so obtained is far too great for the mind to grasp. How much less, then, can we conceive of the size of the sun, whose diameter is 866,000 miles, and which would contain 1,300,000 globes as large as the earth. The best way of arriving at the rela-

tive sizes of the bodies is to make a small model of them. Thus, if we select a globe two feet in diameter to represent the sun, the earth will on the same scale be but $\frac{22}{100}$ of an inch in diameter, the size of a very small pea. We must imagine this small pea to be travelling around the globe in a circular path and at a distance of 215 feet from it. Meanwhile, if we look sharply, we will see a small shot, $\frac{5}{00}$ of an inch in diameter, moving around the pea about six inches away. This, on the same scale, accurately represents the moon. (There would be seven other particles revolving about the globe, the seven other planets, but these we need not consider.)

Imagine now this globe, with the small pea 215 feet away and the shot six inches away from the pea, set out on a level field. We know that the sun and earth are surrounded by stars in every direction; how far away on our model would the nearest fixed star be? The answer is that the nearest fixed star would be represented on the same scale by another large globe placed over 8000 miles away. This conception is of much importance, for it shows us how completely our sun with its minute attendants is isolated in space.

The sun is an immense mass of self-luminous, glowing gas at a temperature of about 18,000° F. It is contracting slowly, and must in time become solid and cold as our earth has done long ago. And as the sun is, so is the innumerable host of stars. They are merely suns, many of them vastly larger and vastly hotter than our sun, which itself is merely a faint bluish star. Whether they have minute particles, or earths, revolving about them as our sun has we do not know. It can only be said that were even the nearest star accompanied by any such planets as revolve about our sun they would be enormously much too small to be discovered by any means which we possess.

It was in the year 1609 that a telescope was turned for the first time toward the sky. One of the most remarkable of the many discoveries which at once followed was the revelation that many of the stars of the sky are not single stars, but double ones; many a star hitherto supposed sin-

gle was found to be really made up of two or more stars so close together that to the naked eye the pair, or group, must always appear as one. The first double star system ever discovered was in Ursa Major—the second star in the handle of the Great Dipper. When we consider the very crude instruments which the early observers had and the many discoveries of absorbing interest by which their researches in almost any direction were rewarded, since at that time everything was unexplored and new, it is not surprising that the significance of this one discovery was lost sight of.

One hundred and sixty-three years later, in the year 1779, Sir William Herschel turned his attention to these double stars, and for fifteen years devoted himself with tireless energy to observing them. He resolved to examine every star in the heavens with the utmost attention and under a very high power, and to measure accurately the relative positions of the stars of each pair that he might detect if there was any motion. The result of his labor was a catalogue of 10,300 double stars, the great majority of which are, however, too wide to form true double-star systems.

The life of this astronomer, who was the founder of double-star astronomy, is an inspiring one. Born to struggle and privation, it was not until his twenty-eighth year that he rose to a position as organist in a chapel at Bath, Eng., and not until his thirty-fifth year that he first looked through a small telescope. "Henceforward," says Miss A. M. Clerke, "the purpose of his life was fixed. It was to obtain a knowledge of the construction of the heavens, and to this sublime ambition he remained true to the end." The story of how he made his own telescopes, grinding the specula by hand while his sister read to him, and how, gradually, his enthusiasm and boundless perseverance led to his wide recognition, is one well known to astronomers.

After a careful examination of the measures which he had made, Herschel gradually became convinced that in many of the double-star systems the components were actually revolving about one another, and in 1802 he demonstrated this in an elaborate memoir. Thus, for the first

time, it became known that a double-star system is composed of two immense suns which, under their mutual attraction, revolve about each other. This astonishing and unexpected discovery at once aroused the greatest interest. Here were revealed numerous systems, inconceivably remote from our solar system, greatly larger than it and totally unlike it. Would the same law of gravity, which so amply accounts for the motions of the planets and their satellites, also govern the motions of these new bodies? The motions of the double stars were henceforth to be carefully observed and the results investigated with the highest power of mathematics.

The son of Sir William Herschel was to continue his father's work, retiring for that purpose to the Cape of Good Hope that he might explore the southern sky. He possessed a very superior instrument for that day, the telescope being eighteen inches in diameter and twenty feet long, and the outcome of ten years' continuous labor was the discovery and measurement of over two thousand pairs in the southern hemisphere.

Meanwhile the great German astronomer, William Struve, beginning work in 1824 at the ill-furnished observatory at Dorpat, measured, with the utmost precision, 3112 double stars, and these measures were made with such elaboration and care that they will long remain the most important contribution to double-star astronomy ever made by one man. After the death of Struve the work was continued by his son, who, during the next fifty years, discovered many new pairs and added a vast series of measures, the value of which can hardly be overestimated.

Thus, by these and many lesser observers, the work of discovery and measurement was carried forward until 1870. Prior to this date it was held by astronomers that the field for the discovery of double-star systems had been about exhausted. The Struves, with the great telescope of Poulkova, had repeatedly and critically examined all the brighter stars of the northern sky, some 140,000 in number, and it seemed reasonable to suppose that little in the way of discovery remained to be done. Thus Sir James South, who had pur-

posed to take up this work anew, while standing in his observatory said to Prof. O. M. Mitchell, "Here, sir, you behold the wreck of all my hopes. Here I have expended thousands, but it is all over, and there's an end. Struve has reaped the golden harvest among the double stars, and there is little for me now to hope or expect." "It would be difficult," adds Professor Mitchell, "to appreciate the feelings which at this time were sweeping through the mind of the astronomer. Long-cherished visions of grand discoveries in the heavens, which for years had played round his hopes of the future, had fled forever. Another had reaped the golden harvest, and, like Clairault, who wept that there was not for him, as for Newton, the problem of the universe to solve, Sir James South could almost weep to think that another's eye had been permitted to sweep over the far distant realms of space which he had long hoped might be his own peculiar province."

In the year 1869, Mr. S. W. Burnham, an amateur astronomer of Chicago, ordered a small six-inch telescope of Abram Clark & Sons, of Cambridge. This seems an unimportant fact enough, but it was to mark an epoch in the history of double-star astronomy. For this new but enthusiastic observer, who, after a long day's work at the office gave up his nights to searching the heavens, was soon to make the first of those brilliant discoveries which have given to us nearly thirteen hundred new pairs, and have forever disposed of the idea that the Struves had more than entered the borderland of exploration. Burnham's stars are, for the most part, very close and difficult. On this account their motion is very rapid, and they will doubtless furnish as much information about the growth and nature of the stellar systems, and furnish it more quickly, than will all the earlier discoveries combined.

Among the double-star systems there are two which, from the way in which they were discovered, are of special interest.

Some who are here may have seen the following picture or rather the two following pictures, placed side by side. The first, representing Herschel in his observatory at the

end of his great telescope as, while searching over the heavens, he discovered the planet Uranus. The second showing the astronomer Le Verrier at work at his study table. Underneath the pictures is written, "Two ways of discovering a planet." For Le Verrier, while writing down figures at his table, was discovering the new planet Neptune with the same absolute certainty as that with which Herschel at his telescope discovered Uranus.

In 1844, the German astronomer Bessel, from a discussion of observations made with the meredian circle, became convinced that Sirius and Procyon, the two bright "dog stars," were each attended by an invisible companion. Not only this, but the weights of the companions, and the orbits in which they moved, were computed with accuracy before they had ever been seen by any astronomer. It was not, indeed, until 1862, that the companion to Sirius was observed for the first time, with the telescope of the Dearborn Observatory, and astronomers had to wait thirty-five years longer before the little attendant to Procyon was revealed through the great 36-inch telescope of the Lick Observatory. But in each case the excessively faint companion was found to be in the position and following the path assigned to it half a century ago.

One hundred and twenty-two years have elapsed since Herschel made his first observation upon a double star. During this period there have been about 110 astronomers who have given attention to this work. As a result, there have been catalogued about 13,000 double stars and on many of them a large number of measures have been made, though it is to be remarked that the observers are still all too few in proportion to the work to be done. Let us see what the mathematical astronomers have deduced from all this material.

In the first place, it is found that the smaller star is revolving about the larger one in an ellipse, just as the planets pursue elliptic paths about the sun, but with this important difference: that while the orbits of the planets are almost circular, the orbits of the stars are, on the whole, very much flattened—the ellipse is much longer than it is wide. Again,

by a simple application of the principle of the lever, the relative masses of the two stars of a double-star system can be readily obtained. Unlike the solar system, in which the sun is nearly 800 times larger than all the planets combined, the two components of a double-star system are of comparable, and frequently of nearly equal, mass. Evidently these systems are very unlike the solar system. They are, in short, made up of two great suns revolving about one another in exact accordance with the law of gravity; although it has not yet been rigorously proved that this is the only possible law which will account for the motions observed, yet the probability that it is the law of attraction in these systems is so great that it amounts almost to a certainty.

The recognition that the law which governs the motions of these bodies about one another is that same law which so amply accounts for the complex motions of the bodies in our own solar system has led to an investigation so vast and far-reaching that it constitutes one of the most exalted conceptions of modern astronomy.

There are in the sky a multitude of faintly shining, self luminous, cloud-like bodies called *nebulæ*. What they consist of we do not certainly know—whether they are wholly gaseous, or whether they are made up of a vast number of meteoric particles which, by their mutual collisions, give rise to the faint light which the nebulæ are seen to emit. The larger of these nebulæ are very irregular, but the smaller are usually circular or elliptical in outline, and some of them have a star at their center. Now the force of gravity acting upon such a great nebulous cloud in space will cause the particles to move ever nearer and nearer together—that is, the nebula will slowly contract, or shrink, under the influence of its own gravitation. And as it shrinks together it will grow hotter and hotter, as can be proved mathematically, until in time it will become as compact and as hot as our own sun. Helmholtz, indeed, in 1856 proved that our sun is thus steadily shrinking to the extent of about 250 feet a year, and that this contraction is the source of all the heat which we receive from it. As long as the shrinking mass remains

gaseous, it will emit light and heat, and it is believed that just before the contraction is stopped by the increasing resistance of the now nearly solid mass the heat emitted and the brightness will be greater than at any previous time.

But there is another factor to be considered. Unless we suppose an almost impossibly delicate adjustment of its particles, the nebula, as it contracts, will begin to rotate about some axis. And it will rotate faster the smaller it grows. If this rotation is not too great, the nebula will condense into a single body like our sun, but otherwise it may take a very singular form closely resembling an hour glass, or pear. This pear-shaped body, which the French mathematician Poincaré first showed mathematically to be possible, has been named the *Apioid of Poincaré.*

The contracting nebula cannot, however, long retain this pear-shaped form, which is known to be an unstable figure of equilibrium. Its future history will be as follows: The constriction separating the small end of the pear from the large end will increase until, finally, the small end is cut away and begins to revolve about the larger portion close to its surface. But two such gaseous, elastic bodies revolving so close together will raise enormous bodily tides in one another and the effect of these tides will be to push the two bodies rapidly apart. Thus, from the contracting nebula, there will have been evolved by the action of gravity alone a true double-star system. But we can trace the evolution still further than this. As long as the bodies remain plastic, the enormous tide-raising force which they exert upon one another will not only push them apart, but it will continually increase the flattening or elongation of the orbits, and we have seen that these flattened orbits are characteristic of the double-star systems.

It should be added that the *apioid* is by no means the only form which a contracting nebula may take. If the rotation is too great for this body to occur it seems probable that there will be a general thinning out of the material near the axis of rotation and that the mass will take the form of a ring; but it is to be observed that the ring is an unstable figure of equilibrium also, a temporary stage in the evolu-

tion, the next step of which we cannot foresee. And so, with a different adjustment of the rotation to the mass, still other forms can doubtless rise; but their mathematical discovery is of the utmost difficulty and it remains still unaccomplished.

Thus we have traced, briefly, what seems to have been the past history of the stellar systems. Their evolution, begun countless ages ago, will go regularly on until, at an epoch inconceivably remote, it will cease through the cooling and solidifying of the component stars. The life of man on the earth is so short compared with these immense intervals of time that the slow process of the development will be forever withheld from his direct vision. But by patient study of those laws of nature with whose action he is already acquainted, the history and aspect of the heavens in the remote ages may be revealed to him. Thus, although he may view the stars as it were but for an instant, he may come to know of them—their beginning, their life history, and their end.

ELECTROLYTIC CHROMIUM.

With a divided cell containing a chromic salt at the cathode and an acid or saline solution at the anode, good deposits of chromium can be obtained on a carbon cathode, or on platinum, brass, lead, etc., according to the experiments of Neumann, which were published in *Zeitschrift für Elektrochemie*, and abstracted in a London journal. With chromic chloride solutions containing 10 per cent. Cr, a current density per square decimeter of 0·9 ampère gave only oxide, 1·8 to 7·2 ampères gave oxide and metal, 9 to 18 gave pure metal, in the latter case mostly crystalline, with a current efficiency in densities 9 and upward of about 38 per cent. Increase of temperature hardly affects the current efficiency, but above 50° C. the metal deposits as a black powder. A strength of 16 per cent. Cr in the solution gives a yield of 57 per cent., increased to 89·5 by altering the anode solution. With chromic sulphate the best conditions are 6·7 to 8·5 per cent. Cr and 13 to 23 ampères per square decimeters, giving 84·6 to 86 per cent. efficiency. Acetate does not work well. The deposits are bright gray and lustrous, but have a tendency to peel off, due to films of oxide. They are hard and brittle and very pure, containing only 0·1 to 0·2 per cent. of iron, and, like ordinary chromium, occur both in active and passive states. The decomposition potential in chromic sulphate of five times normal strength is 1,898 volts, in the chloride 8 times normal 1,685 volts, but it is necessary to use at least double this electro-motive force.

Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, October 16, 1901.*]

HALL OF THE INSTITUTE,
PHILADELPHIA, Wednesday, October 16, 1901.

Vice-President WASHINGTON JONES in the chair.

Present, 148 members and visitors.

Additions to membership since last report, 15.

President Birkinbine, who assumed the chair, introduced Mr. Alex. J. Wurts, of Pittsburgh, who gave an interesting description of the Nernst incandescent electric lamp, as modified and improved by himself and associates in connection with the Westinghouse Electric and Manufacturing Co. This American type of lamp is now so far perfected that the company above named is about to place them upon the market.

Mr. Wurts recounted the numerous difficulties which had been encountered and successfully overcome in adapting the crude invention of Nernst to meet the conditions of practical service.

Mr. Wurts had installed a number of the new lamps in the lecture room, which was brilliantly illuminated.

The subject was discussed at considerable length by Messrs. C. J. Reed, Prof. Arthur J. Rowland, Carl Hering, Richard L. Binder, Spencer Fullerton and others.

(An abstract of Mr. Wurts' remarks, with the discussion, will appear in the *Journal* in due course.)

On Mr. Fullerton's motion the subject was referred to the Committee on Science and the Arts.

Prof. Rowland, numerously seconded, moved a vote of thanks to the speaker of the evening for his admirable presentation of this interesting subject. The motion passed unanimously.

Adjourned.

WM. H. WAHL,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of proceedings of the stated meeting held Wednesday, October 2, 1901.*]

MR. LOUIS E. LEVY in the chair.

The following reports were adopted:

(No. 2113.) *The Liszt Organs.*—The Mason & Hamlin Co., Boston, Mass.

ABSTRACT.—This subject was referred to the committee by the Bureau of Awards of the late National Export Exposition. The Liszt organ is a musical instrument whose tones are produced exclusively by reeds actuated by exhaust wind. Its development has covered a period of many years, during which

the manufacturers have improved it in every detail of tone-quality and volume, elastic and highly-responsive touch, evenness of scale, with numerous orchestral effects of real artistic merit. The development of the instrument has proceeded during the past 25 years.

The report concludes: "In recognition of the intrinsic merits of the Liszt organ, and of the skill and ingenuity displayed in its production, the Franklin Institute awards to its makers, the Mason & Hamlin Company, the Elliott Cresson Medal. [*Sub-Committee.*—H. R. Heyl, Chairman; Chas. M. Schmitz, Paul Sentz, Rich. Zeckwer, Wm. Stoll, Jr., Henry C. Wilt.]"

(No. 2150.) *The Morse Drive Chain.*

ABSTRACT.—The chain under consideration was first placed on the market as a bicycle chain, but was not satisfactory in service on account of the sprockets not being properly cut to fit it. When this defect was remedied the results were more satisfactory.

The exhibits submitted to the committee showed both patterns, but the roller feature was not considered, the rocker-pin being the vital element of the improvement.

The sub-committee visited the establishment of Wm. Sellers & Co., in Philadelphia, and examined one of these power chains operating a key-seating machine. This chain had run for several months and was working smoothly and about as quietly as a belt. The report concludes: "From all the information the committee's representatives could obtain, and on examination of the patent records, they believe that this improvement in chain construction is an important one, and is a step towards raising the efficiency of what heretofore has been an unsatisfactory method of transmitting power. The John Scott Legacy Premium and Medal is recommended to the inventor, Everett F. Morse. [*Sub-Committee.*—Geo. S. Cullen, Chairman; L. L. Cheney, J. Logan Fitts.]"

(No. 2151.) *Tobacco Cutting Machines.*—John B. Adt, Baltimore, Md.

ABSTRACT.—These machines are protected by letters-patent of the United States granted to applicant. The machines have come largely into use and perform their intended service most satisfactorily.

The principal mechanical advantage of these machines lies in the peculiar motion of the cutter knife. The down-stroke or cut is made vertically, giving an even cut, the motion of the feeding attachment being arrested while the cut is being made. The length of the cut is very easily adjusted by means of a worm, and fixed by a lock-nut, while the stroke of the ratchet on the same side of the machine is changed.

As the knife is being raised it is, by an ingenious arrangement of eccentrics, given a motion which takes it away from the tobacco which is being fed forward for the next cut. By this ingenious expedient the friction is avoided which would frequently generate sufficient heat to change the color of the tobacco, and affect unfavorably its commercial value. The distance between the two planes of action of the cutter-knife is always greater than the thickness of the next cut, the material for which is being fed forward while the knife is being raised.

The Adt machines are said to be unique in possessing this anti-friction movement of the cutters, and the great advantage which this movement affords in always leaving the tobacco with its original bright color is freely acknowledged by manufacturers who use the machines.

The material and workmanship on the machines is pronounced excellent. One machine inspected by one of the committee's members had been in operation continuously for several years, without any expense for repairs. It was running at the rate of 360 cuts per minute and was working perfectly, making a very fine cut. The usual speed is 260–275. The Adt machines finally are said to require less power to operate them than other machines of less capacity. The John Scott Legacy Premium and Medal is recommended to the inventor. [*Sub-Committee.*—Wm. F. Willcox, Chairman.]

(No. 2167.) *Color-Sense Tester.*—E. W. Scripture, New Haven, Conn.

ABSTRACT.—The purpose of this device is to test the color vision of persons engaged in occupations in which ability to distinguish colors is essential.

Light passes through white glass, then through glasses of different colors. The person under examination names the colors; from a comparison of the correct names with the names he gives, the accuracy of his color vision is determined.

The Scripture apparatus consists of a circular disk of white glass, about 8 centimeters in diameter, held in a brass frame to which a handle is attached. Over this disk is a thin sheet of metal pierced near its periphery by 10 holes regularly spaced. Attached to the center of this is an axis which carries one or more of the detachable disks. All of these are approximately the same diameter as the brass frame about the white glass.

One disk has 10 holes covered by glass of colors used in signaling. These colors are matched spectroscopically with the colors in practical use.

The second disk has 10 holes covered by glass ranging in shade from clear to smoked. The third disk has 5 holes which are uncovered. These are not equally distant, but are so located that one of them is opposite a hole in one of the previously described disks; the 4 other holes are also opposite to the holes in the other disk. All the holes so far mentioned are about 1 centimeter in diameter and are equi-distant from the centers of the disks.

The fourth disk is like the third, except that its holes are about 1 centimeter in diameter.

Method of Making the Tests.—A dark room is to be used in making tests with this instrument. The two eyes are examined separately. The color tester is fastened upon the front of a lantern, holding either an incandescent lamp or an oil flame. Three tests are made. In the first, the disc with red and green glass is placed upon the axis, and on this the disc, with five large holes. Light passes through the white glass, then through the colored glass, and travels through the five holes to the eye of the observer. He calls off the colors which he sees through the holes, following any prescribed order. Both color disc and diaphragm are turned irregularly and the calling off of the colors is continued. If any mistakes are made, a defect in color vision is proved.

In the second test, the disc with five large holes is replaced by the one with five small holes, and, as before, the observer names the colors. In this case rapidity is insisted upon, for the purpose of this test is to determine whether the central spot of the eye has defective color vision, and, if the test s conducted with deliberation, the eye may turn and permit the light to fall upon peripheral parts of the retina.

In the third test, the disc with colored glasses is put next to the white

glass; upon it the disc with various shades of smoked glass, and finally the disc with the large holes. The purpose of the disc with smoked glass is to imitate the effects of foggy and smoky air upon signal colors. By bringing each of the ten shades of smoked glass in turn before one color of glass, the transmitted light becomes in turn of ten different shades of the same color. The names of the color seen are given as in the two previous tests.

A blank form of record is to be used, on which are entered descriptive details of the person examined and the judgment of the examiner as to whether the color sense of each eye is "safe" or "not safe."

The three important parts of the tester are: (*a*) Discs of colored glass arranged around the circumference of a circle. (*b*) A series of smoked glasses to modify the colors of the discs. (*c*) The use of a small aperture to test for blindness to color in the central parts of the visional field.

Your committee finds that the circular arrangement of colored glasses was used by the L. C. & D. R. R. in England, at least as early as 1890, that the use of the modifying glasses is described in Edridge Green's book entitled, "Color Blindness," published in 1891, and that the method of testing by small apertures was shown at a conversazione of the Royal Society several years ago. Professor Scripture bases his claim "on the combination of the parts in such a way as to reproduce the mental conditions under which the engineer or pilot judges the lights." The committee finds the claim to be substantiated.

Dr. Morris, of the Reading Railroad, after examining the tester carefully, said that he regarded it as a great improvement on the wool-test, and emphasized the point that the pieces of wool soon became too much soiled to be of use while this instrument is unchanged.

The following points of advantage are noted: (*a*) Simplicity of construction. (*b*) Convenience in manipulation. (*c*) Combination of parts as to imitate practical conditions.

The report awards the Edward Longstreth Medal of Merit to the inventor for the excellent manner in which the parts of this apparatus are combined. [*Sub-Committee.*—Geo. F. Stradling, Chairman; Robt. H. Bradbury, Edward A. Partridge, F. E. Ives, Arthur W. Goodspeed.]

(No. 2179) *Combustion Crucible.*—Porter W. Spooner, Easton, Pa.

Reserved for publication in full.

The award of the Scott Legacy Medal and Premium to the inventor is recommended for ingenuity displayed in construction and the practical value of the apparatus. [*Sub-Committee.*—Harry F. Keller, Chairman; G. H. Clamer, Joseph Richards.]

(No. 2180) *Electro-Chord Piano.*—George Breed, Philadelphia.

ABSTRACT.—This invention is the subject of U. S. letters-patent No. 560,679, May 26, 1896 (and others pending). The device in general consists of an ordinary piano, opposed to the springs of which is a series of electro-magnets, one for each tone and semi-tone, in a range of about five octaves, adjusted with their poles in close proximity to the strings, each magnet coil forming a portion of an electrical circuit in which are also a contact breaker beneath the corresponding piano key and a current-interrupting device termed the pulsator, together with the necessary electric generator, and a sliding contact rheostat. Each circuit has its own magnet and contact-breaker, although in general the pulsator, generator and rheostat are common to all circuits.

[The operation of the device cannot be made intelligible without the aid of a number of illustrations.]

Among the novel features of present design of the piano are an elaborate system of electrical commutators and stops controlling their action, by the use of which certain strings may be made to respond more powerfully than certain others, or only the upper or lower tone of a chord may be made continuous, while the others die away as in the ordinary piano; or various combinations of the different qualties of tone produced by several pulsations, either on the piano frame or isolated from it, may be obtained.

The original idea of an electro-musical instrument in which the sonorous body is vibrated by a fluctuating current is not a new one, nor is the tone quality of the present instrument all that might be desired musically. The inventor has, nevertheless, attacked the problem with the display of much ingenuity in the application of his novel improvements, and particularly in the design of the variable pulsator, for which reason the award of the Edward Lonstreth medal is made. [*Sub-Committee.*—Chas. C. Heyl, Chairman; Max Levy].

(No. 2187) *Ink-Eraser.*— Deisher.

(An advisory report).

(No. 2188) *Electrolytic Method for Obtaining Metals and Nitric Acid from Fused Nitrates.*—J. V. Darling, Philadelphia.

(Reserved for publication in full.)

The following report passed first reading:

(No. 2196) *Experiment in Long-Distance Phonographic and Telephonic Transmission.* Wm. J. Hammer, New York. W.

SECTIONS.

(*Abstracts of Proceedings.*)

Physical Section.—*Stated Meeting*, September 25th, 8 P.M. Dr. Geo. F. Stradling in the chair. "Crystallization Under Electrostatic Stress." Dr. Paul R. Heyl. Second communication. (Abstract.) The thought underlying these experiments was that if crystals were allowed to form from solutions subjected to severe and intermittent electrostatic stress, they might bear some birth-marks of the stormy circumstances attending their formation. An alteration of interfacial angles was deemed the most likely change, and a change of density was also examined for. No effect of either kind was found in crystals of sulphur in CS_2, or in crystals of copper sulphate in water. Also solution of HgI_2 in hot alcohol and in hot HCl were used as qualitative indicators. Under electrostatic stress, this salt crystallized out in the ordinary and very unstable yellow form. It was hoped that the nascent crystals would form the more stable red modification from the beginning. The conclusion drawn is that any molecular forces called into play by electrostatic stress are not comparable with the forces of crystalline attraction.

"Recent Progress in Electricity." Dr. M. G. Lloyd. In reviewing the current literature on "Electricity," the speaker called attention to di-electric polarization by mechanical means, to the dependence of the Hall-constant upon thickness when very thin films are used, to recent measurements of thermo-

magnetic, thermoelectric and galvanomagnetic phenomena, to the theory of electrons, to recent experiments affording evidence of the non-existence of any counter E M.F. in the electric arc, and to numerous minor articles. He dilated at greatest length upon the recent discussions as to whether a moving static charge produces the same magnetic effects as an electric current, inaugurated by Crémieu's announcement that his experiments failed to show such an effect. At present the weight of evidence is in support of Rowland's famous experiment made in 1876 at Berlin, which showed the existence of the effect in question.

"Review of Recent Work in Light."—Dr. Horace C. Richards. The speaker briefly reviewed the following papers:

In the subject of refraction, F. Pockels (*Physik. Zeit.* **2,** 693) has investigated the variation in the refractive index of glass with change of density produced by pressure. The purpose of the paper is to amplify the results obtained by Pulfrich in 1892 (*Wied. Ann.* **45,** 609) on the temperature change of the refractive index, and to test the various formulæ connecting refractive index with density.

In spectroscopy, work has gone on in the accumulation of data, the chief interest being the grouping of lines in series and the search for numerical relations Mention may be made of the work of H. Lehmann (*Ann. Phys.* **5,** 633) on the ultra-red spectra of the alkali metals; that of Lockyer and Baxandall (*P.R.S.* **68,** 189) on the arc spectrum of vanadium; and that of Schenck (*J.H.U. Circ.* **20,** 79) on the cadmium spectrum.

An interesting theoretical paper by W. Sutherland (*Phil. Mag.* [VI] **2,** 245) on the cause of the structure of spectra seeks to explain Balmer's and Rydberg's laws by the hypothesis of electrons revolving about vibrating atoms.

K. Angstrom has contributed a paper (*Ann. Phys.* **6,** 163) on the absorption of radiation by carbon dioxide, showing that while increase of the thickness of the column of gas merely darkens the absorption bands, increase of density broadens them.

R. W. Wood has published several papers on the anomalous dispersion of cyanin and carbon (*Phil. Mag.* [VI] **1,** 36, 405, 624) measured by interference and by refraction through thin prisms Another paper by him (*Phil. Mag.* [VI] **1,** 551) on the abnormal refraction of sodium vapor is of significance in the theory of the solar "flash-spectrum."

In the domain of psycho-physical optics, a paper by S. Bidwell (*P.R.S.* **68,** 262) describes his later investigations on the "negative after-image" produced in the eye by a brief flash of color after a period of rest.

The most striking of the recent advances have been in the theoretical development of the laws of the distribution of radiation in the spectrum of an "ideally black" body. The most recent result is that derived by M. Planck (*Verh. Dts. Phys. Ges.* **2,** 202) by assimilating the radiating molecules of matter to Hertz resonators; and this theory has been subjected to rigid experimental scrutiny by Paschen (*Ann. Phys.* **4,** 277) by Rubens and Kurlbaum (*Ann. Phys.* **4,** 649) and by Lummer and Pringsheim (*Ann. Phys.* **6,** 192). The result seems to be that while Planck's formula is a very close approximation to the truth, there are small systematic deviations. The most remarkable contribution in this subject is by Planck (*Ann. Phys.* **4,** 553, 564)

where he shows how the law of radiation and the kinetic theory of gases lead to the determination of molecular constants, such as the number of molecules in a cubic centimeter of gas, etc.

E. Pringsheim has contributed (*Vehr. Dts. Phys. Ges.* **3,** 81) a theoretical derivation of Kirchoff's law connecting emission and absorption, which seems free from objection.

The radiation of bodies not ideally black has also been investigated. Lummer and Pringsheim (*Verh. Dts. Phys. Ges.* **3,** 36) have used the law of radiation to obtain limiting values for the temperature of several incandescent bodies, and E. L. Nichols (*Phys. Rev.* **13,** 65, 129) describes an investigation of the comparison of the visible radiation of carbon with that of the acetylene flame.

Dr. Richard's communication was discussed by Mr. Hugo Bilgram and Professor Hoadley, and Dr. Lloyd's by Drs. Stradling, Seal and Meeker.

On motion of Dr. Meeker, a vote of thanks was tendered the gentlemen who presented papers. JESSE PAWLING, JR., *Secretary.*

SECTION OF PHOTOGRAPHY AND MICROSCOPY.—Proceedings of the *Stated Meeting*, held Thursday, October 3, 1901, at 8 P.M. Dr. Chas. F. Himes in the chair. Present, 16 members and visitors.

The Executive Committee, through Dr. Leffmann, reported informally on the season's program of communications.

The Special Committee appointed at the previous meeting to prepare and present a scheme of Photographic-Record Work for the section, presented a report, which was read.

The Executive Committee, through Dr. Leffmann, gave an informal report of the present state of the subject of the proposed photographic exhibition, from which it appeared that no definite plan had yet been decided on.

The report of the Special Committee on Record Work was taken up for consideration. Mr. Ridpath and Mr. Wanner exhibited several styles and sizes of albums and commented on them. Criticisms were offered by the chairman on the absence in the classification of any reference to scientific records, and on the specification of size of pictures. The subject was very fully discussed by Messrs. Leffmann, Ridpath, Truscott and others. The drift of the discussion disclosed the general sentiment to be in favor of an extension of the plan of classification to include the scientific element, but not to curtail the general scope of the same.

On Dr. Leffmann's motion, duly seconded, it was finally

Resolved, To refer the report back to the Special Committee with instructions to extend the proposed classification so as to include specifically subjects of scientific interest; also, that the Special Committee be given power to act, and that the members be invited to transmit suggestions to the committee.

WM. H. WAHL, *Secretary pro tem.*

MINING AND METALLURGICAL SECTION. Thirty-third *Stated Meeting*, held Wednesday, October 9th. Vice-President James Christie in the chair. Present 15 members and visitors.

The evening's communications were devoted to a series of informal talks on the metallurgical arts at the Pan-American Exhibition, participated in by Messrs. Birkinbine and Christie.

Mr. Wm. R. Webster, by invitation of the chairman, made some interesting remarks on recent progress in the manufacture of rails. He also made reference to the paper of Mr. Risdale, read at the recent meeting of the British Iron and Steel Institute, Glasgow, and commented on a table made up by that author, exhibiting the different types of faults in steel, and the causes of their development.

Mr. A. E. Outerbridge made some remarks on iron cast in iron moulds, and its use in foundry work.

Mr. J. S. Jeans, one time Secretary of the British Iron and Steel Institute, a visitor, was introduced by the chairman, and made some happy informal remarks on the industrial conditions prevailing in Great Britain and the United States, more especially bearing on the iron and steel industries.

Mr. Christie closed the meeting with some comments on the remarks of the last two speakers, and added some comments of his own on the possibilities of the future utilization of low-grade iron ores after concentration, especially in the open-hearth process. WM. H. WAHL, *Secretary pro tem.*

MECHANICAL AND ENGINEERING SECTION.—*Stated Meeting* held Thursday, October 10th, 8 P.M. Mr. James Christie in the chair. Present 104 members and visitors.

The subject for discussion was "The Construction and Inspection of Steam Boilers," with especial reference to the "City of Trenton" disaster.

The subject was announced by the chairman in a few appropriate remarks, and Mr. Samuel M. Vauclain was invited to open the discussion.

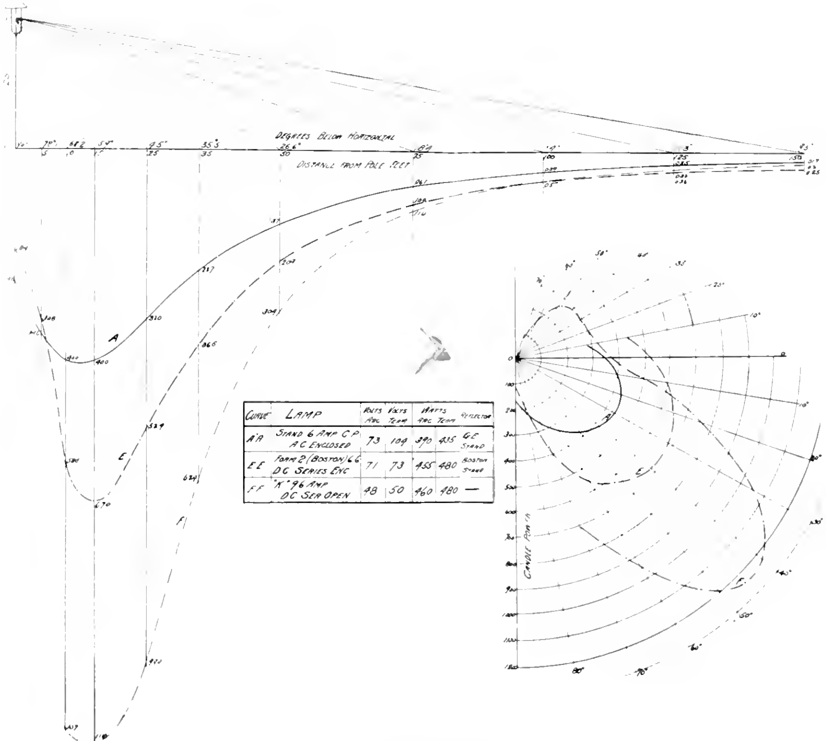
Messrs. S. M. Vauclain, John M. Hartman, Robt. F. Kinney, Geo. Hartley, the chairman, and a number of others participated. [The discussion is reported in full for future publication.]

DANIEL EPPELSHEIMER, JR., *Secretary.*

ELECTRICAL SECTION.—*Stated Meeting*, held Thursday, October 17, 8 p. m. Professor Hoadley in the chair. Present, 42 members and visitors.

Messrs. Eglin and Hering spoke interestingly on "The Electrical Arts at the Pan-American Exposition." Mr. Eglin went into some detail concerning the progress which had been made by the Westinghouse Co. in perfecting the Nernst lamp, and an exhibition of the quality of these lamps was given with apparatus which had been allowed to remain in circuit since the regular meeting of the Institute. The fine quality of the light impressed those present very favorably. Slides were also shown illustrating some of the fine lighting effects at the Pan-American Exposition. Mr. Hering's remarks were to the effect that the novelties at the Exposition were rather few, but spoke regarding the progress which had been made in storage battery design, and also regarding the control of the circuit furnishing light to the Exposition, mentioning in detail the high potential switches and the number of lights in circuit.

RICHARD L. BINDER, *Secretary.*



Curve	Lamp	Volts Arc	Volts Term	Watts Arc	Watts Term	Reflector
A'A	Stand 6 Amp C.P. A.C. Enclosed	73	104	390	435	G.E. Stand
E E	Form 2 (Boston) 6.6 D.C. Series Enc	71	73	455	480	Boston Stand
F F	"K" 9.6 Amp D.C. Ser. Open	48	50	460	480	—

FIG. 11.—ILLUMINATING CURVES.

TO THE BINDER.

Being advised that in a number of instances this plate, which appeared in our November issue opposite page 368, was mutilated, and having no knowledge of the extent to which this may have prevailed through the edition, this duplicate is here inserted to replace such mutilated copy should it be found in the volume you are binding.

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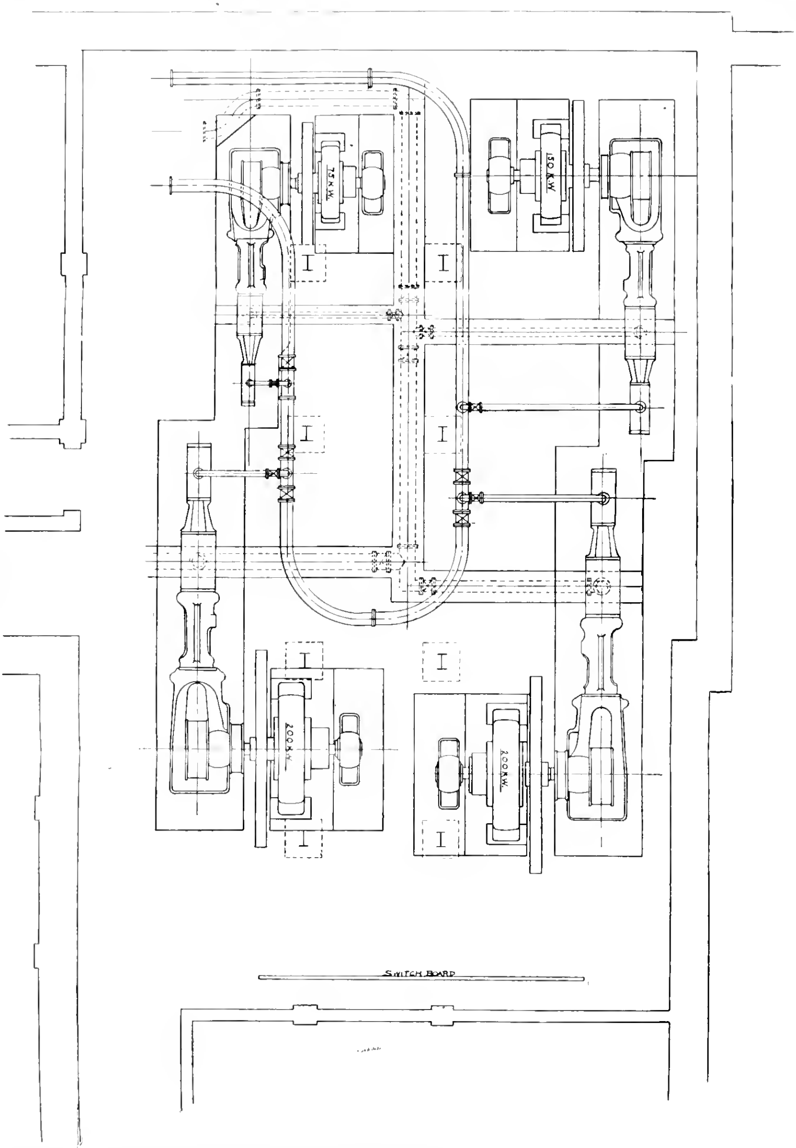
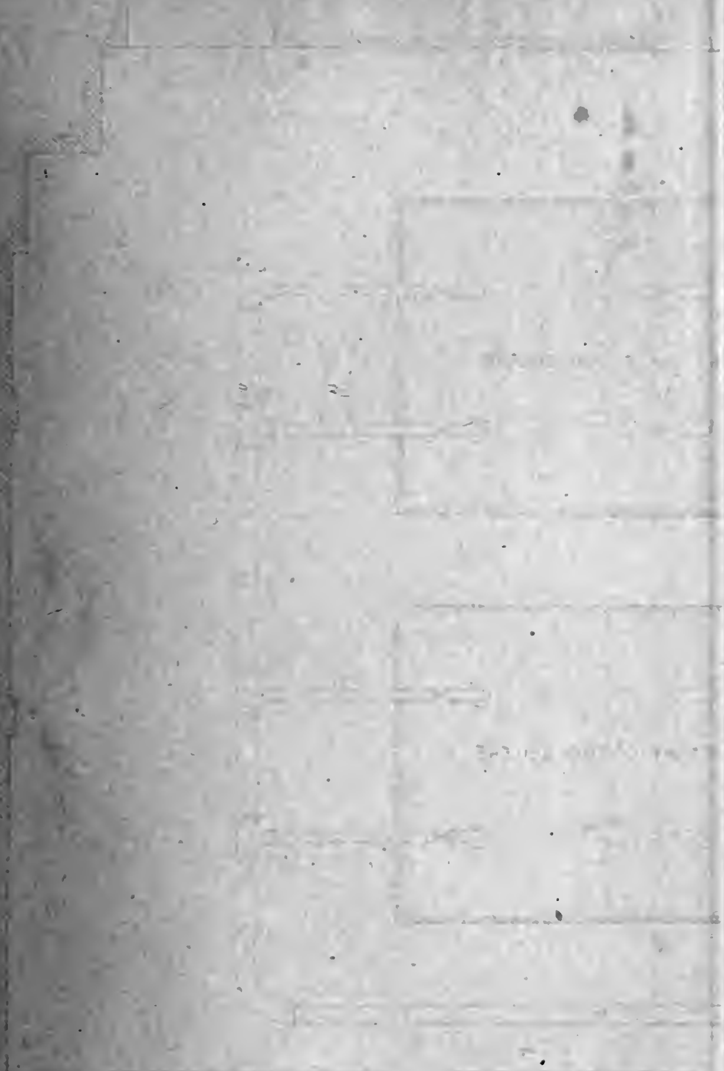


Fig. 13—Plan of engine room, U. S. Mint, Philadelphia.



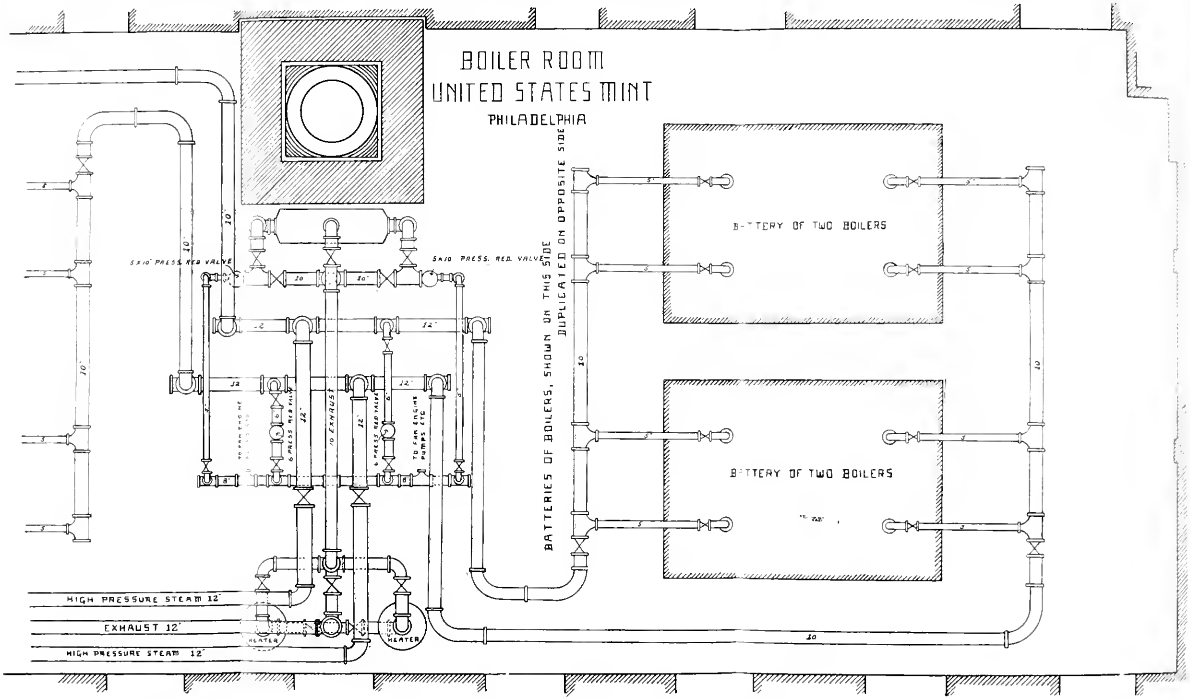
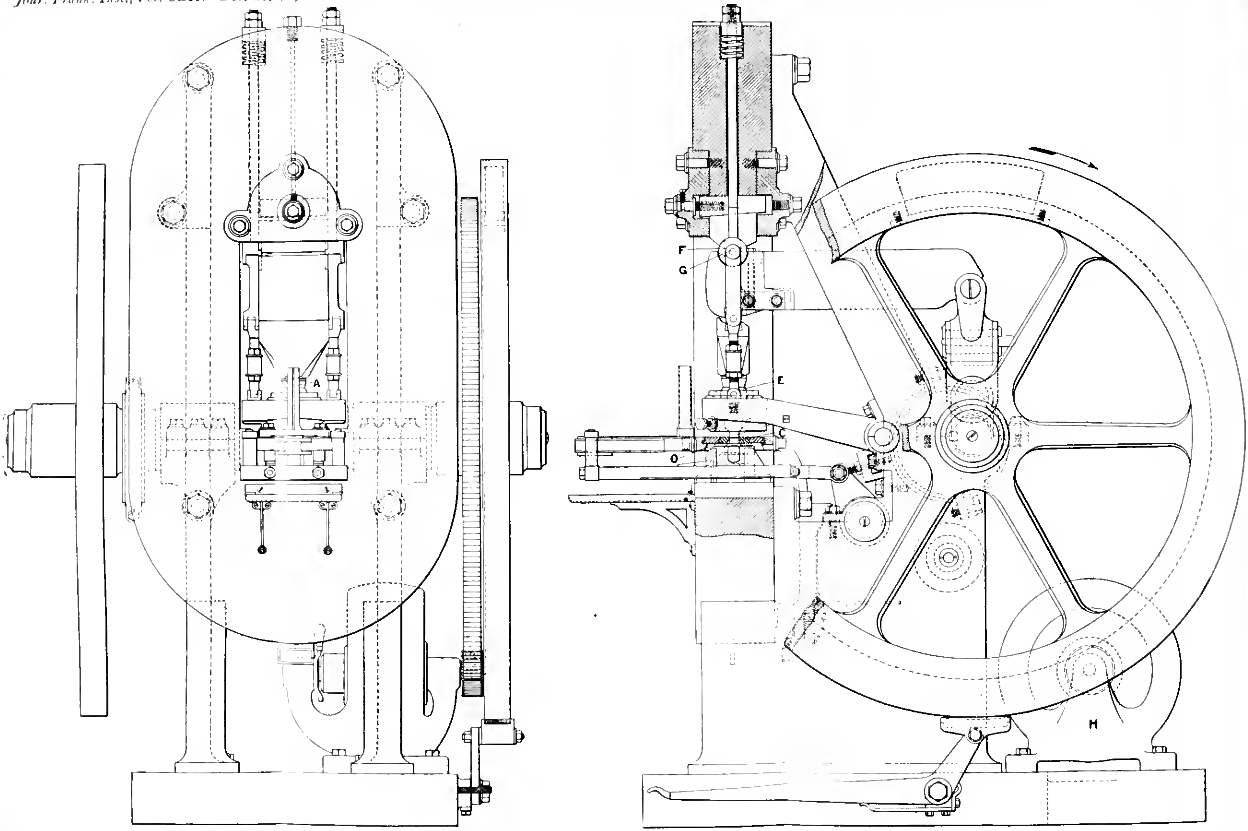
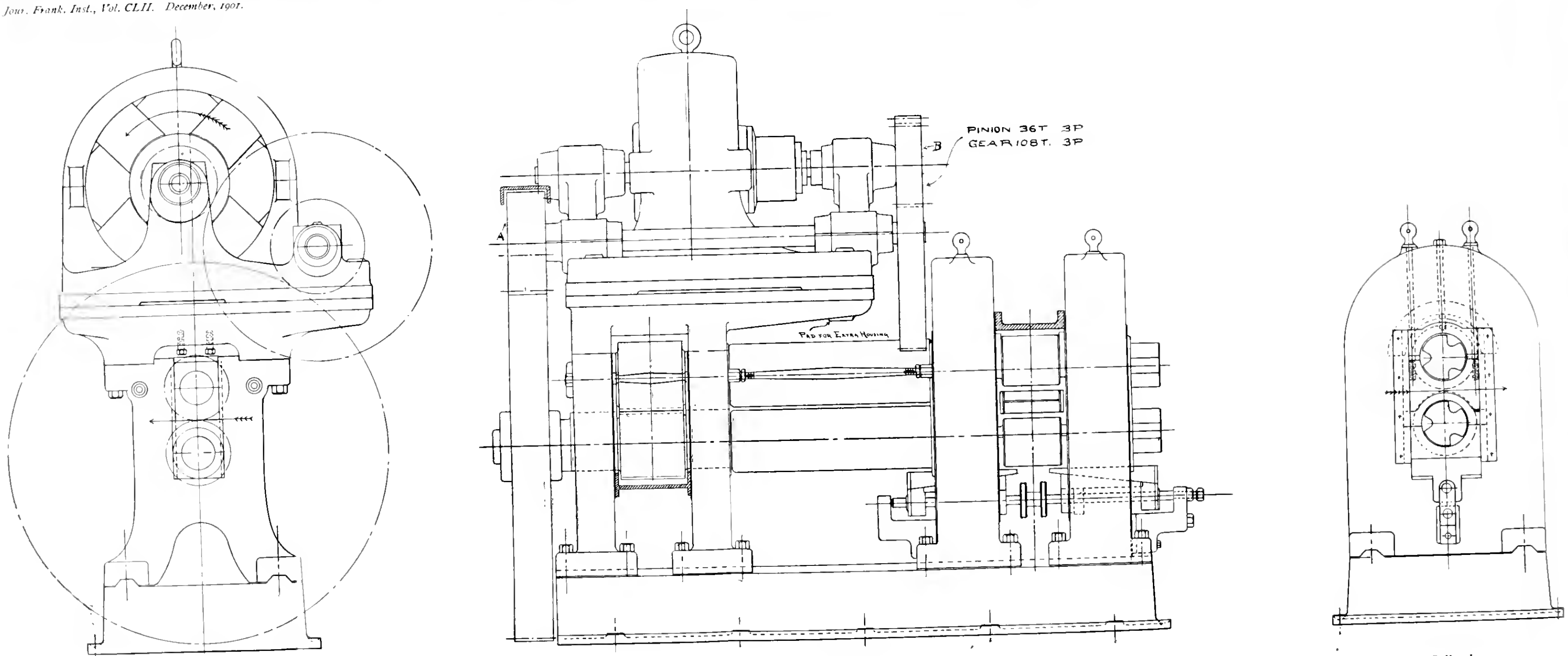


FIG. 12—PLAN OF BOILER ROOM, U. S. MINT, PHILADELPHIA.



Front view. *Side view.*

FIG. 7—COINING PRESS.



Motor end.

Front view.

Roll end.

FIG. 1—10″ x 9″ ROLLING MILLS, U. S. MINT, PHILADELPHIA.

JOURNAL

OF THE

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OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CLII, No. 6. 76TH YEAR. DECEMBER, 1901

ELECTRICAL SECTION.

Stated Meeting, held Wednesday, June 19, 1901.

MINTING MACHINERY AND APPLIANCES

BY EDWIN S. CHURCH.
Superintendent of Machinery U. S. Mint, Philadelphia.

The electrical equipment of the new United States Mint is comparatively simple, similar devices being found in many modern shops, so therefore I will present to the Electrical Section of the Franklin Institute a general outline only of the mechanical operations involved in the coinage of money, together with a brief description of the various installations.

The equipment will include several new features, which as yet are in an experimental stage, and will not be alluded to in this paper.

The development of coining machinery is necessarily slow, since the manufacture of money is confined almost entirely to governmental institutions, which limits the de-

mand for this class of machinery. Again, in many of the coining operations, the judgment of the operator is of such importance that it is impossible to substitute apparatus which would eliminate this personal factor.

The necessity of accuracy and the difficulty in maintaining a uniform standard is appreciated only by those who are in daily touch with the work.

The mixing of gold and silver, while in a heated condition, with their respective alloys, casting into ingots, rolling and cutting into planchets, annealing and whitening, and finally the stamping, all depend, more or less, upon the skill and judgment of the operator.

No set rules can be laid down for this work that will give uniform results for the different melts, or even for two strips in the same heat, which often vary beyond the tolerance, although they have passed through identical operations, so far as human judgment can determine.

Again, the law compels us to work by weight, and since the blanks are cut from dies of the same size, the variation in density and hardness must be compensated for by varying the thickness of the blanks. Occasionally, blanks have been found, on calipering, where the lighter pieces measured about .0003 of an inch thicker than the heavier pieces.

Innumerable theories have been propounded for securing greater accuracy, new schemes suggested and tried, but ninety per cent. have failed, because, when tested from a practical standpoint they were found to be worthless.

It is, comparatively, a simple matter to secure good results from a small amount of metal when it is handled with extreme care in the melting and annealing furnaces, but when you attempt from data secured in this manner to frame rules for the working of tons of metal daily, some of which is hard and brittle, the rest tough and soft, the proposition is entirely different.

This was forcibly illustrated when experiments were made to eliminate the draw-bench and wood furnaces. These experiments were started two years ago, and it was only recently that the results justified the adoption of finishing rolls and automatic strip furnaces for silver.

The following table gives the weight, fineness, tolerance and diameter of all pieces coined at the mint at the present time:

Denomination.	Legal Weight. Grains.	Fineness. Per Cent.	Tolerance. Grains.	Tolerance. Per Cent.	Diameter.
Double Eagle	516	90	·50	·09	1·350
Eagle	258	90	·50	·19	1·050
Half Eagle	129	90	·25	·19	·850
Standard Dollar	412·5	90	1·50	·36	1·500
Half Dollar	192·9	90	1·50	·77	1·200
Quarter Dollar	96·45	90	1·50	·155	·950
Dime	38·58	90	1·50	·388	·700
Five Cents	77·16	75Cu 25Ni	3·00	·388	·800
One Cent	48·	95Cu 2½Sn 2½Zn	2·00	·416	·750

The tolerance is the amount the coin is allowed to vary above or below the legal weight in grains, and, as shown in the next column, the ratio of this amount to the weight of individual pieces is a varying quantity ranging from ·09 per cent., with the double eagle, to ·416 per cent. in the one-cent piece. Of course, the denomination in which the tolerance is the largest per cent. of the legal weight, is the easiest to coin; for instance, the one cent, as shown in table, ranks first in this regard, and the double eagle is the most difficult.

Although the regulations call for a certain thickness for the various denominations, it is not considered in the coining operations, since, if the diameters are kept intact, the thickness must vary with the density of the metal.

After the metal is properly alloyed it is run into ingots, and the ends are cut off by an appliance known as a topping machine, which is run by a 3 horse-power motor; the power is transmitted from the motor to the machine by means of a belt; this, together with the cutting-presses, is the only machine used in coining operations on which a belt is used.

Four of these machines will be required.

The ingots are then rolled out by break-down rolling mills which are driven by 50 horse-power motors, and then finished to their proper thickness by mills driven by 25 horse-power

motors. These motors are arranged with countershafts, running at 300 r.p.m., through the base. The pinions *A* and *B* are made of raw-hide, in order to reduce the noise. Six break-down and four finishing mills will be used to start operations during the first year.

The mills, as shown in *Fig. 1*, have 10 x 9-inch rolls, with 7-inch necks, and are made of chilled iron.

Experiments will soon be made to substitute steel rolls, but it is a question if the efficiency will be increased enough to justify the extra expense.

These rolling mills have several features which, to the best of my knowledge, are utilized only in mint operations. The adjustment is obtained by means of wedges situated under the lower roll, which is capable of adjustment in a vertical direction, and by means of a graduated dial the movement can be adjusted to ·0005 inches. All mills will, in the future, be fitted up with the solid wabbler instead of one consisting of three or more pieces. This reduces the excessive pounding, which cannot be eliminated from wabblers of the latter type.

To determine the proper speed for rolling has been a subject of considerable experiment. Two years ago, a rolling mill was constructed so that the speed could be varied. Velocities, ranging from 40 to 160 feet per minute, were tested, and, finally, 117 feet surface velocity of material passing between rolls was adopted. Faster than this causes difficulty for the operator who receives the strip, and there is also liability of the feeder passing two strips instead of one through the rolls.

The rolling mills will be substituted for the old-fashioned draw-bench and a 25 per cent. saving in the condemned silver blank will be possible. As yet this method for the gold denomination is in an experimental stage.

The strips are then cut into blanks by cutting machines, which are driven by 3 horse-power motors. Nine of these will be used.

During the rolling operation the strips are annealed by an automatic heating machine, which propels them through an oven heated by gas, and it should be noted that the

increase of standard blanks is largely due to the efficiency of this machine.

Before leaving the mechanical operations which have been alluded to in this article, I wish to emphasize the difficulty of proper annealing, which is a source of trouble to all workers in metal, and is no doubt due, to a great extent, to the difficulty in controlling the temperature and handling the material while in a heated condition.

In most establishments less thought and time is spent in perfecting this department than any other, yet we find, in the mint, that this is the most important operation through which the metal passes.

Any process, such as forging, drawing, rolling or spinning in which the metal is subject to considerable strain or pressure, tends to harden the material in a comparatively short time, and when we consider that it requires a 50 horse-power motor to reduce a silver strip, approximately 1½ inches by ⅜ inches by 4 feet, only ·016 inches during one passage, it would seem strange indeed if a considerable molecular change could not be detected. To restore the ductility to the metal, a constant temperature of the proper degree must be maintained, and without going into detail respecting the requirements of the various metals, the following is a general scheme which shonld be followed:

The proper degree of heat for the various metals must be distributed over the surface without relying upon the conductivity of the metal for equalization, and the flame must be non-oxidizing when gold or silver is to be worked with their alloys.

The work at the mint has shown that the old idea of annealers to allow the metal to "soak," after it has been brought up to its proper heat, is of no benefit, especially where the fineness has to be maintained within the government limits; the material should be withdrawn as soon as heated.

Gold is now annealed in the automatic furnaces by remaining in the flame approximately seven minutes—that is the time required in passing through. The wood furnaces required a strip to remain in the fire about forty

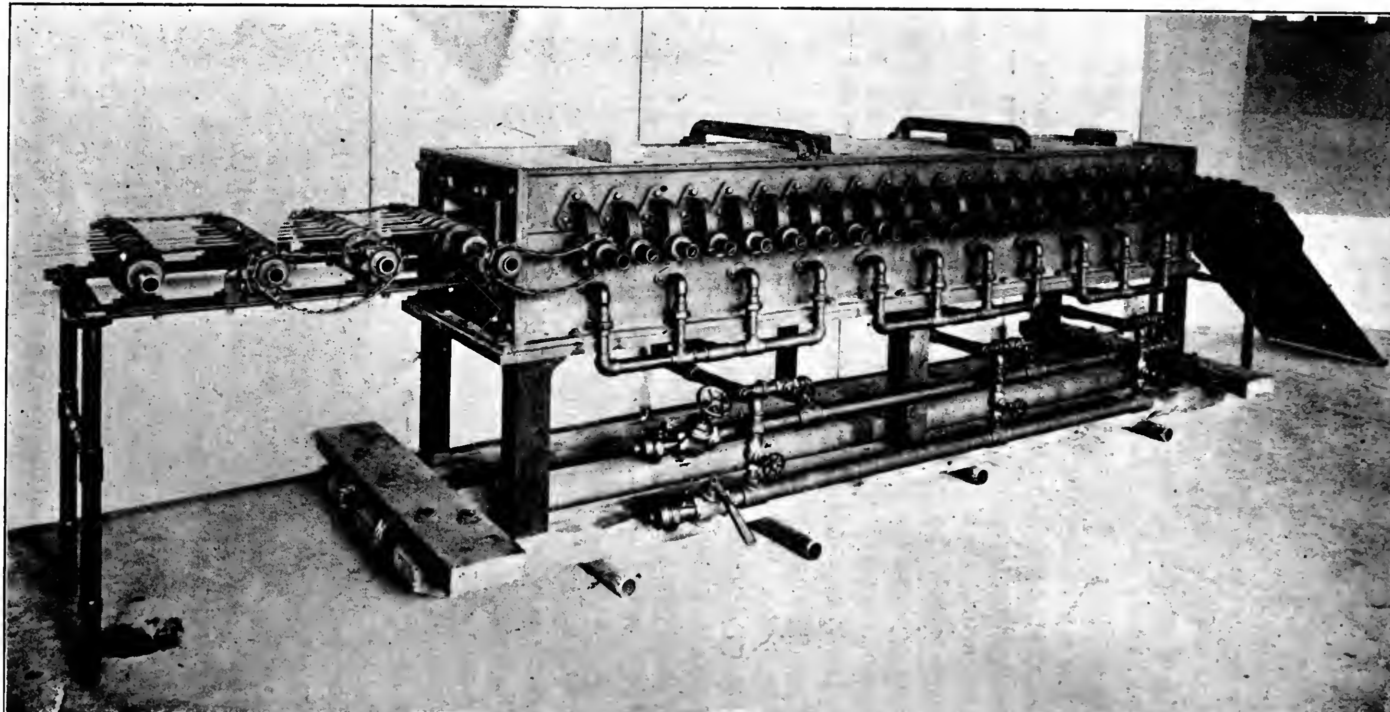

FIG. 2—Annealing furnace.

minutes. *Fig. 2* is a photograph of the first machine built of this kind, and is similar to the new ones, except that the cooling attachment is not shown. Instead of the strips being cooled by hand a fine spray of water is thrown upon them before they are exposed to the air, which prevents oxidization. They can then be handled without gloves or tongs.

The heating machine will be driven by $\frac{1}{2}$-horse-power motor, and the variation in speed is secured by means of cones which run at 120 r. p. m. The reduction of speed is obtained by worm and worm wheel, as shown in *Fig. 3*.

The blanks are then upset by a machine, as shown in *Fig. 4*, driven by a 3 horse-power vertical motor. Nine of these were designed and built at the mint.

The planchets are then annealed by rotary-heating machines and cleaned with a diluted solution of sulphuric acid.

The furnaces are driven by $\frac{1}{4}$ horse-power motors geared into a shaft passing through a cone, and the power is transmitted to furnace by means of a belt. This scheme is shown in *Fig. 5*.

The rotary-heating machine (*Fig. 6*) consists of a wrought-iron cylinder surrounded by a cast-iron cylinder. The metal is carried through the outer cylinder by a worm and then dropped, in a heated condition into a receptacle and is ready for the bath.

The planchets, after the cleaning operation, are stamped. This is done by means of the coining press, which is, without doubt, one of the best-designed machines in the building, and is shown in *Fig. 7*.

The planchets are fed in the tube A by the operator, and placed in collar O by means of the fingers. The end of the travel of fingers is shown by the dotted position, L. The fingers are opened and closed at the end and beginning of the stroke by means of the friction-block, which travels in grooves.

The upper die, B, actuated by the horizontal beam through the toggle, gives the obverse impression, while the lower die, C, imprints the reverse side. As the dies come

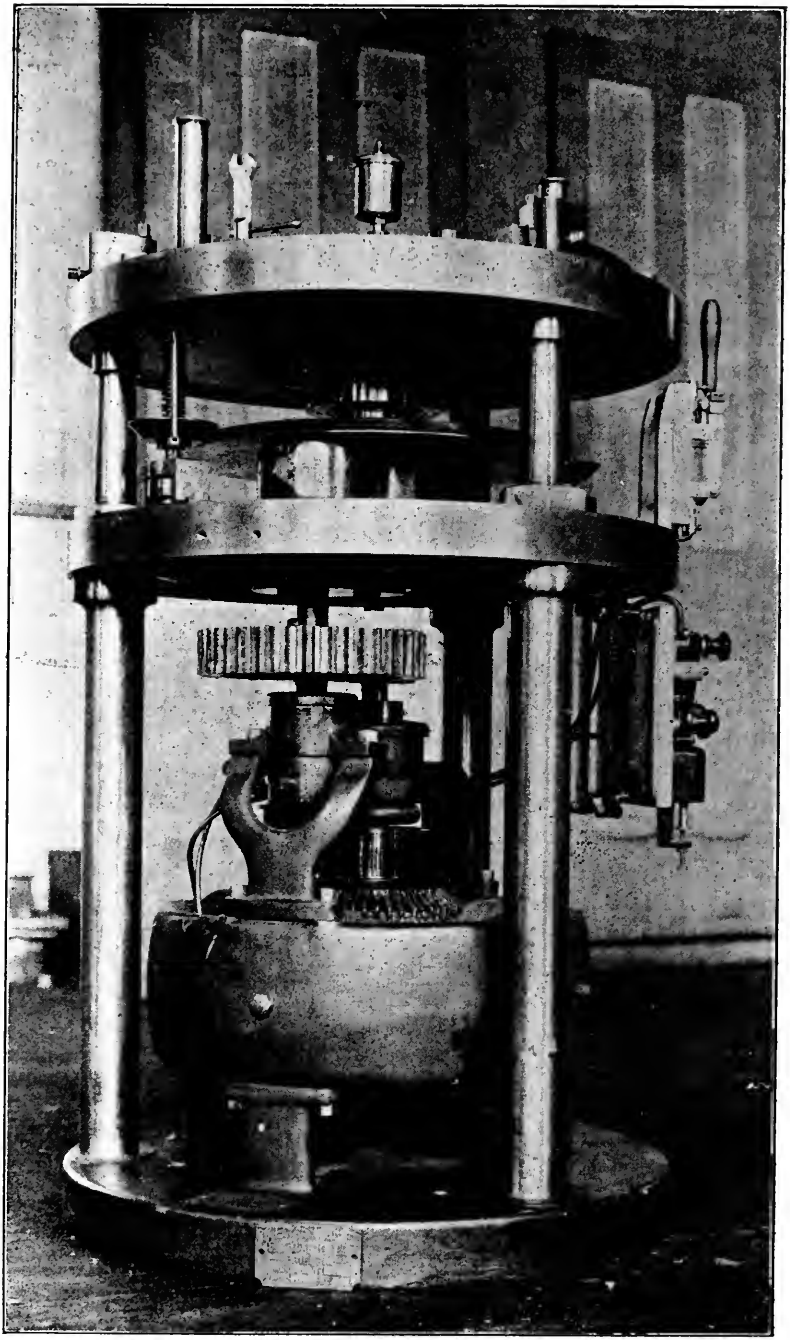

FIG. 4—Upsetting machine.

together the metal is pressed in the grooves of collar, C, giving the reeding on the outer edge. After the stamping operation is completed the fingers return to their first position, J, and on feeding the next planchet pushes the stamped coin aside, which has been forced out of the collar by the raising of the lower die.

On account of the excessive pressure amounting approximately to 160 tons for a dollar, the bearings of the toggle must be very hard, and lapped to a proper bearing.

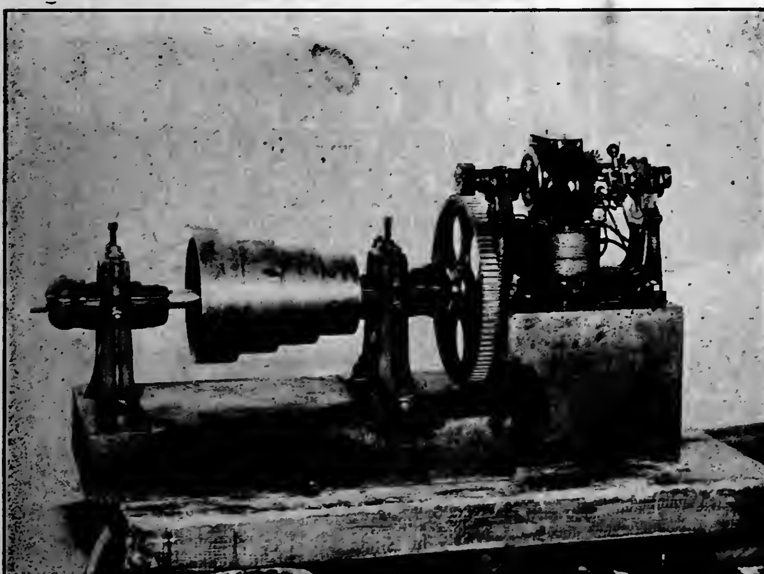

FIG. 5—Geared speed-reducer.

Twenty-three coining presses are to be installed: the larger ones, capable of coining all denominations, will be equipped with $7\frac{1}{2}$ horse-power motors, and the small presses, which are used for denominations up to and including quarter dollars, are equipped with 3 horse-power motors.

The above is only a general description of minting operations, omitting the automatic weighing machines, adjusting, ringing, or the test for resonance, and the several

precautions necessary to preserve the standard of excellence expected of the Mint.

As a result of the new annealing operations, a noticeable change has been observed by the mint officials in the color and appearance of the gold coins. This effect is due to the naphtha gas flame, which does not oxidize the copper used as an alloy, consequently the gold has a much deeper color, preserving the true color of the government alloy.

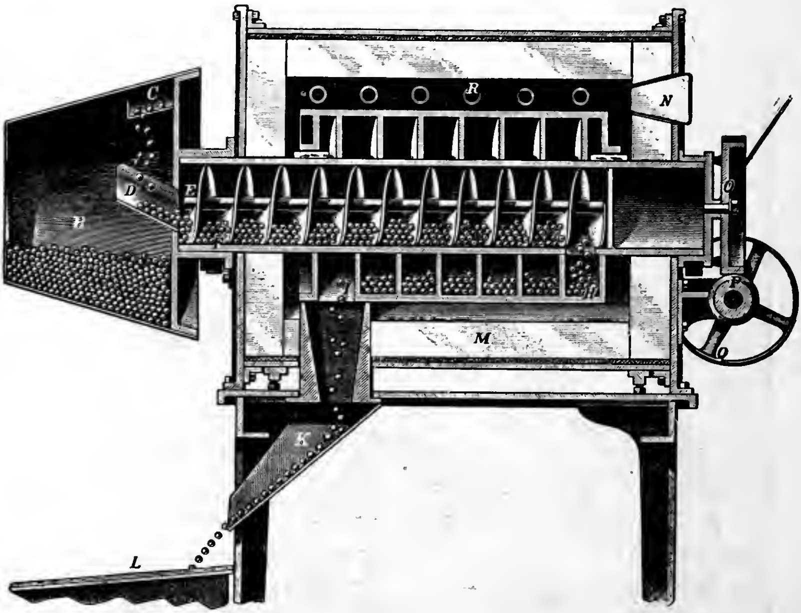

FIG. 6—Rotary furnace.

These improvements in annealing are due to the efforts of the American Gas Furnace Company, of Elizabeth, N. J., the coöporation of the Treasury officials and the determination of the Superintendent of the Mint to secure the best equipment possible for the new building.

The following is the number and size of the motors which will be used for coining operations:

H. P.		TOTAL H. P.	
3 —	3 —	9	open-type countershaft through base.
4 —	7½ —	30	" " " " "
1 —	15 —	15	" " " " "
2 —	25 —	50	" " " " "
1 —	35 —	35	" " " " "
6 —	50 —	300	" " " " "
14 —	7½ —	105	" "
34 —	3 —	102	" "
1 —	10 —	10	" "
2 —	15 —	30	" "
1 —	5 —	5	" "
4 —	¼ —	1	" "
12 —	½ —	6	" "
2 —	10 —	20	enclosed type.
2 —	20 —	40	semi-enclosed type.
1 —	12 —	12	" " "
4 —	10 —	40	" " "
2 —	10 —	10	" " "
1 —	3 —	3	" " "
1 —	5 —	5	open reversible.
2 —	3 —	6	" "
1 —	10 —	10	suspended from ceiling.
1 —	5 —	5	" " "
9 —	3 —	27	vertical type.
111		876	

SPECIAL CONNECTED MACHINES.

There are two directly connected sets. Capacity of dynamos, five hundred ampères at 5 volts each; fields to be excited from 220 volts.

The following are a few special motor connections: *Fig. 8*, 30 x 30-inch x 6-inch planer; *Fig.* 9, milling machine; *Fig. 10*, 24-inch lathe; *Fig. 11*, blower for gas purposes.

On account of the 220 volts which are used for power and lighting purposes, the starting boxes for all motors except those for 50 horse-power are provided with magnetic blow-outs, overload, and no voltage release. The contact buttons are also staggered.

The boiler plant as shown in *Fig. 12* consists of eight boilers, 150 horse-power each, arranged in four batteries carrying 125 pounds pressure and equipped with down draft furnaces. The gases from boilers can be passed through fuel economizer to an exhaust fan or directly to chimney.

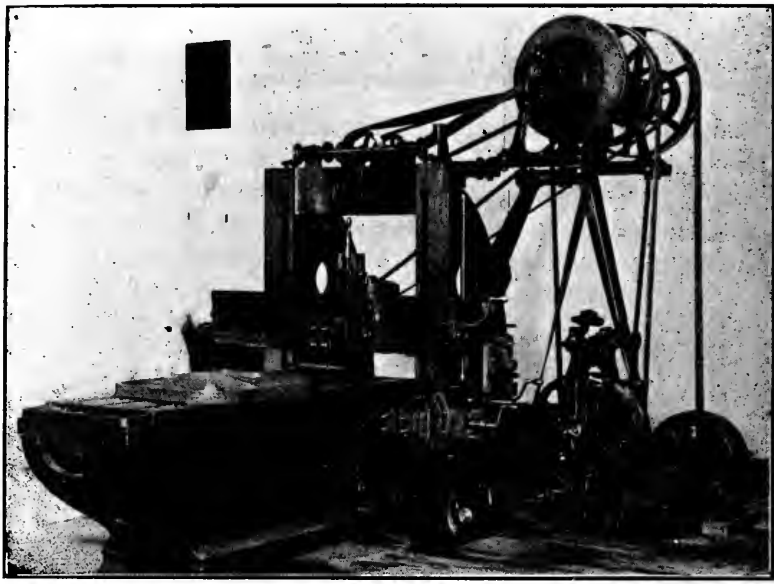

FIG. 8—30″ x 30″ x 6′ planer.

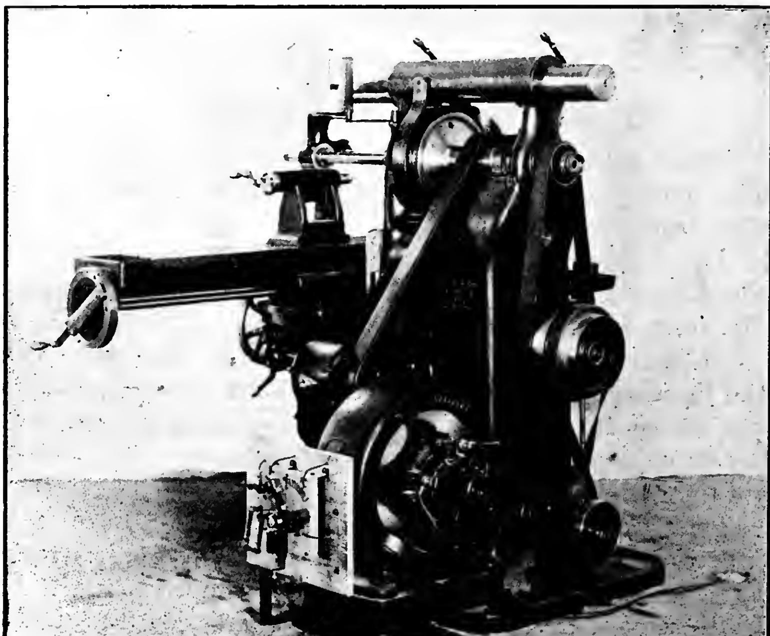

FIG. 9—Milling machine.

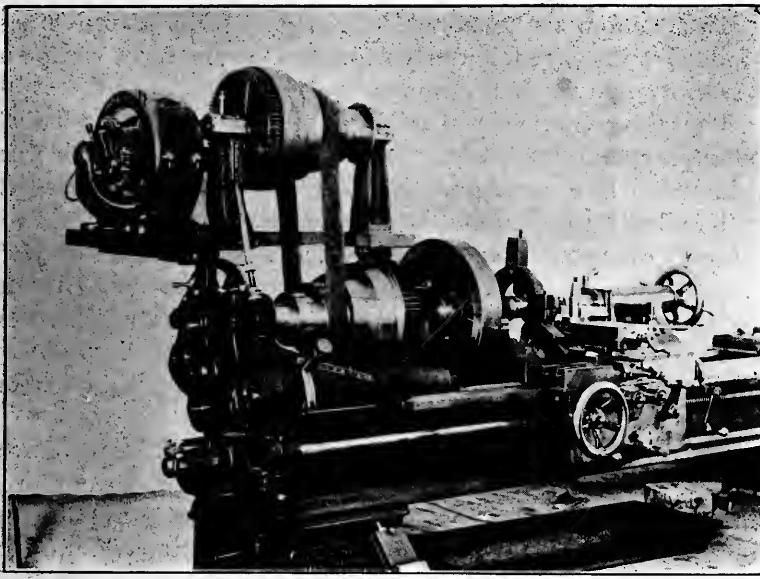

FIG. 10—24″ lathe.

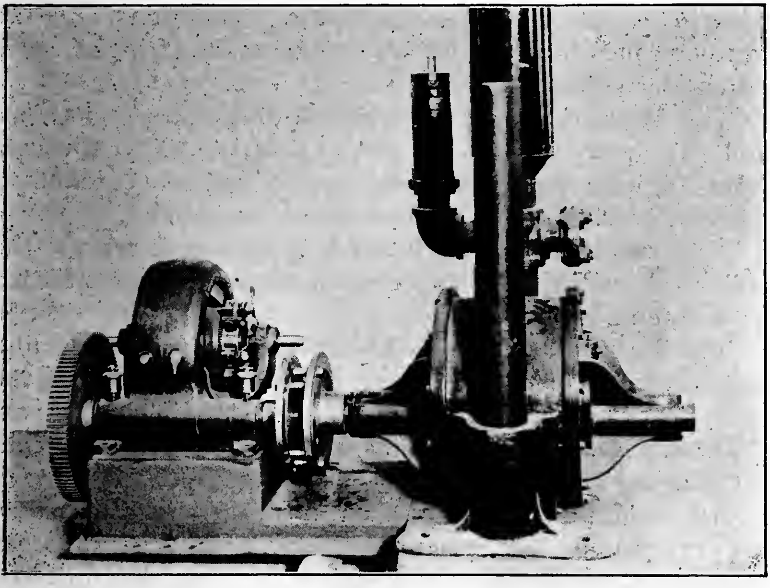

FIG. 11—High-pressure blower.

The economizer consists of twenty sections of ten tubes 4 inches diameter each and are cleaned by means of scrapers driven by two vertical engines.

The feed water is heated by a 700 horse-power vertical exhaust steam feed water heater, and together with the economizer is so arranged that any or all can be by-passed.

The draft to chimney is augmented by an 8 foot fan, capacity of 2,500 cubic feet of gas, at a temperature of 300° F. per minute. The fan runs at 200 r.p.m. and can be parted at an angle of 45° to the horizontal through center of shaft, to facilitate repairs. It is driven by two 25 horse-power vertical engines and so arranged that either one can be thrown into service.

There is also provided a steam nozzle for chimney draft capable of giving a draft equal to 1 inch of water column. The amount of draft is regulated by damper regulators connected to steam drum and also by throttling of the fan engines.

The chimney will not only be used for disposing of gases from the boilers, but also the products of combustion from the furnaces, etc. used in coming operations and the nitrous fumes from the refinery which make artificial ventilation a necessity.

The building is heated by direct and indirect methods, and the apparatus is arranged so that the exhaust steam from engines can be utilized, or by means of reducing valves, live steam direct from boilers can be used.

All condensation from heating apparatus is returned to boiler automatically by two condensation pumps controlled by a pump governor.

The fresh hot-air supply to the various rooms in building is introduced after passing over heated coils, and the fresh air is taken through openings provided for that purpose, after passing through air filters and delivered to central heating chamber by means of fans.

All steam piping is in duplicate, and arranged for carrying 125 pounds for generating sets, seventy pounds for pumps and engine fans and atmospheric pressures for heating system.

Two steam horizontal condensation pumps, $7\frac{1}{2}$ x $4\frac{1}{2}$ x 6 inches, and two vertical boiler feed pumps, 9 x 6 x 6 inches, are installed with their respective piping, so that any or all can be used.

The generating plant consists of four direct connected generating sets, as follows:

Two 200 kilowatts, 100 r.p.m.; one 150 kilowatt, 135 r.p.m.; one 75 kilowatt, 150 r.p.w.

The engines are of the tandem, compound, non-condensing Corliss type, connected directly to their respective generators, and their guaranteed efficiencies are as follows:

200 kilowatts, 21½	pounds of water	for indicated	horse-power	per	hour.
150 kilowatts, 22	"	"	"	"	"
75 kilowatts, 23	"	"	"	"	"

The two 200 kilowatts are to be used for coining operations during the dav, the 75 kilowatts for night work, and the 150 kilowatts for lighting purposes. Practically, no provision is made for gas-lighting in the new building, and it will be necessary for the power plant to supply current at all hours of day or night.

Fig. 13 shows the general arrangement of the various sets.

The high-pressure piping is designed so that steam can be shut off any engine without interfering with the remaining sets.

The connections between the generators and switchboard are made by lead-encased, rubber-insulated cables, carried in ducts varying in size from 450,000 circular mils to 1,200,000 circular mils.

The switchboard is constructed of pink Tennesse marble, 2 inches thick, and is divided into panels, as follows: Four for generators, two for lighting circuits, and the remainder for the motor circuits throughout the building, The busbars for lighting and power circuits can be used independently, or by means of a switch can be connected. Double-throw switches enable the operator to throw generators on either lighting or power circuits. For the power circuit the circuit-breakers are of the one-throw type, consisting of two arms connected together, and switches are used in conjunc-

tion. The lighting panels have the independent arm, double-throw-type circuit-breaker, and are used without switches.

As far as possible each department has its independent system for power purposes, and as the coining operations consume the major portion of the power, the rolling room alone is supplied with four independent circuits capable of delivering over 500 horse-power. This room is equipped with the 50 and 25 horse-power motors, together with the 3 horse-power motors for the cutting presses.

Twenty-five feeders supply current for approximately 3,500 lights, the majority of which are 16 candle-power and about 400, 32 candle-power. Each of the feeders is supplied with a switch, or the entire lot may be thrown out by pulling one main switch.

Fifty-one telephones connected to a switch board controlled by an operator are installed. The system is of the complete central-energy type, and the operator is notified of a call by the dropping of a shutter connected to its respective phone.

An ink-writing telegraph register, capable of indicating an alarm from any one of thirty-five alarm boxes, is used in connection with fire-alarm gong in the office of the engineer and of the superintendent of machinery. The taps on the gong correspond to the station from which the signal is sent.

Thirty watchman's clocks are placed in various parts of the building for the protection of the immense amount of metal stored in the form of coin or bullion.

The signals are turned in by means of a handle causing a small dynamo at each station to send a current to its respective magnet.

Forty-one time-clocks, connected to a master-clock are installed in order to secure uniform time throughout the building.

A switch-board built of blue Vermont marble mounted on an iron frame-work is located in the guard's room in the basement.

On this board is mounted the fuse block, telephone wir-

ing, fire alarm recorder, American District and Western Union call-boxes, police-telegraph and city fire-alarm boxes and voltmeter switch for testing condition of the various storage batteries which supply the electrical apparatus throughout the building.

The storage battery plant, which is in duplicate, supplies the telephone exchange, fire-alarm system and time-clocks with current.

The battery consists of sixty cells connected to a circuit-changing switch, so that when the switch handle is thrown in one direction thirty of the cells will be thrown in series and made ready for charging. The other thirty are split up in five groups with different members of cells in each group: one supplying the telephone exchange; another, fire-alarm system; third, the gas machine; fourth and fifth, the time-clocks.

The circuit-changing switch is thrown in the other direction when the batteries are discharged, placing the duplicate set in service for the various apparatus.

The scheme for charging is arranged so that it can be done from one of the power panels in engine room which is equipped with circuit breaker and rheostat.

Eight elevators, seven for freight and one for passengers, driven by electric motors and provided with a top-and-bottom limit switch, slack-cable switch, safety switch in car and centrifugal governor, all being in series with the brake magnet and safety cut-out.

Four of these elevators, having a capacity of four tons each, are to be used for carrying the loaded trucks of metal to the various floors, and one is so arranged that by means of a back gear the speed can be reduced and its capacity doubled. This will be used for transferring heavy coining machinery varying in weight from three to seven tons.

The gas equipment includes furnaces, heating machines, etc., throughout the building, and a gas-generating plant.

The installation consists of two independent plants; the larger one has a capacity of 20,000 cu. ft. of gas per hour, has four generators arranged in two sets, and each set in turn is connected in tandem.

The smaller plant is to be used for the assay department, and has a capacity of 2,000 cu. ft. of gas per hour. This plant, in case of necessity, can be thrown in service with either one of the larger ones.

This system manufactures gas by vaporizing naphtha in the presence of warm air, and all the accessories to the vaporizer or generator are simply to keep the pressure and temperature of gas constant by heating the oil, air, and the gas after passing from the generator.

The accessories consist essentially of a feeding tank, which regulates the supply of oil to the generator; water-pressure regulator for forcing the oil from the storage to the feeding tank under constant pressure; the circulating pipes for heating the oil after it passes through the generator; the radiator for governing the temperature of the oil which circulates in the machine; the automatic cut-off, the function of which is to close instantly when the air-pressure is removed; the gas-discharge valve for starting the machine, and an air-supply valve for controlling the air to the pipes which connect with the spraying nozzle in the generator.

A thermometer in series with a storage battery and special valve controls the steam to heating chambers. Four storage tanks, with a total capacity of 32,000 gallons of naphtha, are buried below the basement floor for supplying the various machines with oil.

The number of pieces coined and value of same varies considerably in different mints and depends somewhat upon the local conditions. For the fiscal year ending June, 1900, the Philadelphia Mint coined 152,558,878 pieces, value of which was $71,378,477.61. The total coinage of all the mints was 184,373,793 pieces valued at $141,351,960.36. The coinage of nickel and bronze is confined to the Mint at Philadelphia, and 101,301,753 pieces of the value of $2,243,-017.23 were manufactured.

There is also considerable special work required, and during the same year 50,000 Lafayette souvenir silver dollars and 320,000 pieces in 20, 10 and 5 colones for the government of Costa Rica were stamped.

The Director of the Mint states that the chief increase of coinage for last year was in the subsidiary and minor coins, which surpassed all records and was no doubt due to the extraordinary activity of the retail trade throughout the country.

To handle such a vast quantity of metal, which in a year amounts to tons, not only becomes a mechanical problem but necessitates an elaborate system of checking, weighing, assaying and calculating.

The transportation of metal has grown to large proportions, and the Director of the Mint reports that for the last fiscal year the imports in gold and silver amounted to $79,-829.486.00 and the exports $104,979,034.00. This was in the form of bullion, ore and coin (both foreign and domestic.) The handling of coin causes considerable wear, and last year the loss to the government in recoining $6,662,524.85 in worn and uncurrent coin was $313,334.21.

The care of all this money gives an endless amount of trouble. Huge steel vaults for its storage, equipped with all manner of safety devices, must be under constant surveillance. In the new building the largest and most improved vaults in the world are situated under the front running from 16th to 17th Streets.

Each vault has three doors: the front door, weighing about eight tons, is mounted on ball bearings; the other two doors are arranged in one set and are somewhat lighter than the front one. Four combination locks are used, which can be adjusted to independent combinations.

But with all these appliances for the safety of the many millions, the government must depend more or less on the honor of its employés. Considering the number of men employed, the vast quantity of precious metals handled, it is remarkable how small an amount has been lost.

SOME CHEMICAL MYSTERIES.

It has happened more than once that just as we had firmly established our science upon a basis which seemed as unyielding as the Biblical rock, and had toilfully formulated theories that explained all phenomena with unvarying simplicity, some obscure experimentalist made a discovery which by no

possibility could be twisted and molded to fit the existing system and, indeed, even challenged the truth of all established doctrines. Thus it was that Young and Fresnel overthrew the old emission theory of light with their experiments in the phenomena of interference; and thus our theories of chemical interaction, and even our conception of matter, may be modified by the researches made within the last five years in the field of the radio-active substances.

What chemist formerly would for a moment have thought of attacking the law of Avogadro—the law which tells us that if the temperature and pressure be equal, equal volumes of different gases contain the same number of molecules? And yet a modern chemist, Lord Rayleigh, did find it necessary to test the truth of that law by precise determinations of the densities of well-known gases. If he had never studied the behavior of nitrogen, or if he had considered the discrepancies which he observed in determining the vapor-density of that gas, as errors due to defective observation, as many a chemist before him had done, argon and the other newly discovered constituents of the atmosphere might still be unknown, and many chemical doubts never aroused. Roentgen, too, found it necessary to revive theories of radiant matter which we thought we had long since refuted, and he supplied us with rays which we cannot yet explain. Becquerel increased our perplexity with his thorium and uranium rays. But when M. and Mme. Curie exhibited to our astonished eyes the results which they had achieved with radium and polonium, we were completely mystified and were compelled to admit that there were more things in chemistry than our philosophy had dreamed of. Other chemists have also experimented with uranium, following methods different from those of the Curies, and have obtained additional active substances.

Still another supposed element has been found to mock our periodic system. It has been discovered that thorium, when subjected to the action of acids, yields helium, and that thorium is often associated with radio-active substances.

Helium and its gaseous companions on the one hand, the radio-active substances on the other hand, are mysteries which have so far completely baffled our chemists. And uranium and thorium, elements with which we once considered ourselves thoroughly familiar, are now to us as curious as if they had been but the discovery of yesterday.

If the eccentricities of uranium, thorium and helium, and the mysteries of Roentgen rays cannot be adequately accounted for by our existing chemical system, the question arises: Can our system be wrong? Chemistry is an exact science—at least we had flattered ourselves that it had been at last raised to that eminence. But an exact science is infallible, and will hear nothing of exceptions. Some day a chemist will be found whose mind, broad enough to grasp the scattered facts unearthed in the course of a century of research, will elaborate a chemical system which may prove as revolutionary in its way as the theory of Young; but which will embrace in its comprehensiveness those puzzling gases and radiant substances so utterly inexplicable at present.—*Scientific American.*

AN INVESTIGATION OF THE COST OF POWER.*

BY CLYDE D. GRAY.

(*Concluded from p. 413.*)

PRODUCER GAS.

Kind, Composition.	B. T. U. per Cu. Ft.	Authority.
owson, H-18 : CO-25	143	Poole.
" " 19 " 35	108	" Anth. coal.
" " 17 " 25	147	" Bit. coal.
emens	120	"
rdinary producer	150	Reichelm, *Am. Ma.*, Jan. 10, 1901.
owson	160	*Elect. Eng.*, Jan. 25, 1901.
ond, bituminous coal	155	*Elect. Eng.*, Jan. 25, 1901.
rdinary	135	Donkin, *Eng. Mag.*, Dec., '00.
emens	140	Galloway.
rdinary, heated	156	Webster, *Cass. Mag.*, 13–293.
" Taylor	140	Kerr, " " 18–425.
nthracite coal	137	Taylor, A.I.M.E., 18–859.
tuminous "	157	Taylor, A.I.M.E., 18–859.
rdinary	150	Roberts.
Average	143	

BLAST-FURNACE GAS.

rdinary blast-furnace	100	*Elect. Eng.*, Jan. 25, 1901.
" "	110	Donkin, *Eng. Mag.*, Dec., '00.
" "	98	Kerr, *Cass. Mag.*, 18–425.
" "	100	Booth, " " March, 1901.
Average of all	102	

The preceding tables give an idea of the relative heat-alues of the different kinds of gas. The amount that can e made from a ton of coal is variable and depends upon ie kind of coal and the process by which it is made. erry, in a paper before the A.I.E.E., in 1894, estimated iat the better grades of coal, when used in a Dowson pro-icer, would produce about 160,000 cubic feet of gas.

GAS-ENGINE TESTS.

The following tables contain some tests of different gas-igines using various kinds of gas. Some of these are

* From thesis presented for the degree of master of mechanical engineer-g. Sibley College, Cornell University. 1901.

small and others large, although there are but few tests of the larger sizes, from the fact that they have not been on the market until recently. The amount of gas used per horse-power is in some cases based upon the indicated, and in others upon the developed or brake, horse-power. This is indicated by an *i* or *b* placed after the column.

USING NATURAL GAS.

Kind.	H. P.	Cu. Ft. per H. P.	Authority.
Westinghouse . .	621	9·3 (i)	Miller & Gladden, *Sib. Jour.*, June, 1900.
" . .	67	10·4 (b)	*London Engineering*, Jan. 4, 1901.

The Westinghouse Company will guarantee a gas consumption of 12 cubic feet gas per B.H.P. on their small engines and as low as 10 for the larger sizes. The Standard Automatic Gas Engine Company guarantees less than 15 cubic feet per B.H.P.

USING COAL GAS.

Kind.	H. P.	Cu. Ft. per H. P.	Authority.
Westinghouse . . .	9	14·5 (i)	Budd & Moody, Sibley thesis.
Springfield	12	16·5 "	Spier & Keely, " "
	10	15·5 "	Perry.
		16·6 (b)	*Lond. Eng.*, Jan. 4, 1901.
Campbell		15·4 "	Donkin, *Eng. Mag.*, Dec., 1900.
Otto-Crossley	17	24·1 "	London *Elect. Eng.*, Jan. 25, 1901.
Clerk	9	30·4 "	London *Elect. Eng.*, Jan. 25, 1901.
Atkinson, differential,		25·7	London *Elect. Eng.*, Jan. 25, 1901.
" cycle . . .	6	22·5	London *Elect. Eng.*, Jan. 25, 1901.
Griffin	16	28·5	London *Elect. Eng.*, Jan. 25, 1901.
Forward	6	22·5	London *Elect. Eng.*, Jan. 25, 1901.
Simplex		20·4	London *Elect. Eng.*, Jan. 25, 1901.
Wells Bros.	12	27·8	London *Elect. Eng.*, Jan. 25, 1901.
" "	18	21·0	London *Elect. Eng.*, Jan. 25, 1901.
Premier	61	19·7	London *Elect. Eng.*, Jan. 25, 1901.
	50	17·0 (i)	London *Elect. Eng.*, Jan. 25, 1901.
Railway plant . . .	31	21·0 (b)	Hill & Brocksmit thesis.
Average on B. H. P. .		22·9	

This average is rather higher than can be expected of the best modern engines, for these are all rather small units. About 17 or 18 cubic feet may be expected of the average modern engine of moderate size.

USING PRODUCER GAS.

Kind.	H. P.	Cu. Ft. per H. P.	Coal Lbs.	Authority.
Crossley . . .	142	65·7 (i)	·92	*Lond. Eng.*, Jan. 4, 1901.
Koerting . . .	349	83·2 (b)		Mond gas, Jan. 4, 1901.
	377	60·1 (i)		Mond gas, Jan. 4, 1901.
Diesel	7		1·31	Mond gas, Jan. 4, 1901.
"	170		·88	Dowson gas, Jan. 4, 1901.
Simplex . . .	220	86·8 (b)	1·30	Witz, Dowson gas.
" . . .	59	77·7 "	1.30	Witz, Dowson gas.
			Less than.	
Otto			2·00	Dowson gas.
Simplex . . .	220		·80	*Lond. Eng.*, Nov. 30, 1894.
Crossley . . .	280		1·03	Richmond, *Eng. Mag.*, 10–853.
Otto		(i)	·95	Spangler, *Cass. Mag.*, 9–47.
Crossley . . .		"	·76	Spangler, *Cass. Mag.*, 9–47.
La Tombe . .		(b)	1·60	*Power Quarterly*, 1901.
	100	(i)	1·03	Adams, *St. Ry. Jour.*, June, '00.
	320	"	·81	Adams, *St. Ry. Jour.*, June, '00.
Crossley-Otto .	28	"	1·41	*Trans.* I.C.E., 5–73.
" .	118	"	·76	*Trans.* I.C.E., 5–73.
Atkinson . . .	22	"	1·06	*Trans.* I.C.E., 5–73.
Stockport . .	76	"	·86	*Trans.* I.C.E., 5–73.
		109 (b)	1·25	Adams, *Eng. Mag.*, 16–513.

Average of those on I. H. P., 1·04

Average cubic feet on B. H. P., 82, or on I. H. P., 62·9. These values are only approximate, as the data is not very complete.

USING BLAST-FURNACE GAS.

Kind.	H. P.	Cu. Ft. per H. P.	Authority.
Cockerill	182	116·5 (b)	Donkin, *Eng. Mag.*, Dec., 1900.
"	650	135·7 "	Donkin, *Eng. Mag.*, Dec., 1900.
"	725	101·0 (i)	Donkin, *Eng. Mag.*, Dec., 1900.
Otto type	79·5	79·4 "	Donkin, *Eng. Mag.*, Dec., 1900.
	175	145·2 (b)	Booth, *Cass. Mag.*, Mar. 9, 1901.
Wishaw, Eng. . .		140·0	Booth, *Cass. Mag.*, Mar. 9, 1901.
Cockerill	661	112·9 (b)	Hubert, test at factory.
"	715	102·3 "	Hubert, test at factory.
Acme	15	90·0 "	"Colliery Guardian," quoted in *Eng. Mag.*, 15–140.
Cockerill	575	111·4 "	*Eng. Mag.*, 19–587. Schutte.
Same with blower .		101·0 "	*Eng. Mag.*, 19–587. Schutte.
Frieden	177	133·0 "	*Eng. Mag.*, 19–587. Schutte.
	90	231·0 "	*Eng. Mag.*, 19–587. Schutte.
	100	91·0 (i)	*Eng. Mag.*, 19–587. Schutte.

Average . . . . 115·1

Blast-furnace gas is a very good fuel and is very cheap because it is a wasted by-product. It has been used to raise steam under boilers and the steam used in turn to drive the auxiliary machinery and blowers that are necessary in blast-furnace operation. The gas-engine is coming into use for this purpose, especially in Europe, where some very large ones have been made and installed.

OIL-ENGINE TESTS.

Kind.	H. P.	Lbs. Oil per D. H. P.	Kind of Oil.	Authority.
Campbell . . .	40	·85		
Blackstone . .		·75		
Standard aut. .		·62	Gasoline	*St. Ry. Jour.*, June, 1900.
Banki	25	·53	Benzine	Meyer, *L. Eng.*, Dec. 30, 1900.
"	26	·48	"	
Springfield . .	6	1·67	Gasoline	Spier & Keey, Sib. thesis in 1900.
Diesel	33	·46	Petroleum	*Lond. Eng.*, Dec. 30, 1900.
Priestmann . .		1·20	Kerosene	Guy, "El. Light and Power."
Dopp	10	·43	Petroleum	*Eng. Mag.*, 18–124.
Banki		·46	"	
Mietz & Weiss,	10	·62	Kerosene	*E. W.*, April 10, 1901.

No average can be taken from this table, as the engines tested are of such different sizes and makes, as well as using different kinds of oil. It may be assumed that the use of gasoline or kerosene is less economical than the use of gas. There are cases, however, where it is necessary to use them, in places where gas cannot be procured, or for portable engines that are to be used in isolated plants, or on boats or carriages. The gas-engine using gasoline fuel is therefore a standard form of machine, works very nicely, and is fully as reliable as those using gas.

COST OF GAS POWER.

The cost of power generated by gas-engines is variable and depends upon the kind of gas used, the size of engine, the character of the load and the cost of the material used as fuel. The following table gives some figures on the cost of power produced by different sized engines using the different fuels. The kind of gas used is indicated by a small letter in brackets as well as whether the horse-power is based upon the indicated or brake.

Kind, Place.	Cu. Ft. Gas.	Coal per H. P.	Cost Cts.	Authority.
		1·00	1.00 (b. p.)	*Elect. Eng.*, Jan 25, 1901.
	17		1.02 (b. c.)	
Ordinary . . .	20		.87 (b. p.)	Guy, "Electric Light and Power."
	23		1.50 "	
Schwabing . .		1·50	1.50 "	
" . .			3.00 (b. c.)	
Otto		1·20	.16 (i. p.)	Cost fuel alone, Robinson, "Gas and Petroleum Engine."
Ordinary . . .	200		·56	Eberle, *Eng. Mag.*, 14–687
	250		2.00 (b. p.)	*Elect. World*, 1897, p. 822.
Clausthal . . .		1·73	"	" " 36–457.
		·93	.90 "	Cassier's, 9.
Average engine,			.50 (b. n.)	Kerr, *Cass. Mag.*, 18–425.
	20		2.00 (b. c.)	
Glascow . . .		1·25	(b. b.)	Fuel alone, 18–425.
Ordinary . . .			2.00 (b. c.)	Bolton, A.S.M.E., 20–873.
Average . . .			2.40 (i. c.)	Krone, Dg., *E. W.*, 1900, p. 443.
Crossley . . .		2·05 per K. W.		*Eng. Mag.*, 15–295.
LaTombe . . .		1·60		*Power Quarterly*, Oct., 1900.
Otto		1·00	(b. p.)	
Charon		1·06	"	
Crossley . . .		1·23	"	
Oil engine . .			1.74 (b.)	Guy, "El. Light and Power.
Gasoline engine,			1.50 "	Kerr, *Cass. Mag.*, 18–425.
Diesel			2.00 "	
Ordinary . . .			.66 (b. b.)	Meyer, *Sci. Am.*, Feb. 9, 1901.
" . . .			.83 (b. p.)	
" . . .	25		3.10 (b. c.)	*West. Elect.*, Feb, 23, 1901.
Blast-furnace .	80			Dg., *E. W.*, Jan. 19, 1901.

The letters in the brackets are read as follows: The first one refers to brake or indicated horse-power and the second to the kind of gas used, either natural, producer, coal or blast-furnace.

The costs of gas-engine plants are not very different from those of steam plants. Mr. N. W. Perry, in the *Trans. A.I.E.E.*, 1894, says, that the cost of producers or generators is about $11 per horse-power, which is less than that of steam boilers. He also gives an estimate by Dawson on a plant to have an output of 400 kilowatts, occupying a floor space 27 x 54 feet on one level and costing complete, about $10.38 per horse-power. He also says that gas can be transmitted a distance of 1 mile for a 3,000 horse-power plant with a loss of only 1 horse-power. Gantt, in *Cassier's*

Mag., vol. IX, p. 47, says, that a producer plant less than 1,000 horse-power costs more than a boiler plant, but for larger sizes it is more economical. Kerr, in *Cassier's Mag.*, 18–425, says that the first cost of gas-engine is greater than that of the same size of steam-engine, but the cost of complete plant is about the same. In *London Engineering*, January 4, 1901, is given an estimate on the cost of a plant to develop 2,000 electrical horse-power, using Mond gas with a plant to recover some of the waste products of the gas. The producer and recovery plant was estimated at about $64 per horse-power, which would make the plant compare very well with a steam plant as far as first cost goes.

It may be assumed that, in the average case, the first cost of a gas-engine plant is about the same as that of a steam plant of the same size and capacity, and that it will occupy much less space, besides being much safer in its operation than a boiler plant. It also requires but a small amount of water to run it, and if water is scarce, the same water may be used continually if arrangements are provided for cooling and circulating it through the jackets. A producer plant will need much less attention than a boiler plant, for the modern makes of producers are fed automatically, and they can be run for a short time and the gas stored for future use, although it is better to generate the gas only as fast as needed.

The use of the producer with gas engines is coming into extensive use, especially since the development of the engine in the last few years. The best-known form of producer on the market in this country is the Taylor, which is made in sizes down to 2 feet in diameter, this being large enough to supply a 30 horse-power engine. Any kind of coal may be used in this producer, anthracite being the better, and the gas may be used directly from the producer or it may be passed into a storage tank. The gas is usually cleansed before being used in order to take out the dust and other impurities that would tend to hinder the operation of the engine, although engines have been run direct from the producer. In Europe, they use the gases from blast-furnaces without washing at all and claim that the engines work satisfactorily.

Using coal in a producer in this way, a horse-power hour can be produced for a pound of coal even in the smaller sizes of engine, and this is so much better than the steam-boiler and engine can do, that it will certainly lead to their more extensive use, especially in cases involving only a small amount of power.

ELECTRIC POWER.

After having considered the prime sources of power in the preceding pages, the next thing to deal with is, naturally, the principal secondary source, which is electricity, and it will therefore be briefly treated in the following pages.

Electrical power is of comparatively recent date and was not used to any great extent until 1880, and it may be said that the last decade of the nineteenth century was the one in which the greatest development in this line occurred. The improvements in alternating current machinery and the use of polyphase currents of high potential for the long-distance transmission of power, together with the introduction of the rotary converter and the induction motor have caused phenomenal advances to be made in the use of this kind of power, especially for traction and lighting.

The great advantages of electricity over the other kinds of secondary power are, the ease with which it can be transmitted over long distances with losses in proportion to the amount of power that is so conveyed, its safety, cleanliness, ease with which it can be regulated and controlled, the absence of noise, dust and other objectionable features that are common to most of the other kinds of power, the high efficiencies of most of the electrical machinery, so that there is a smaller loss of power from the prime mover to the point of application of the power, and the adaptability of the electric current to so many uses. It has scarcely any real disadvantages, the principal one being that it is dangerous to handle and have in places where there is liability of fire being caused by its presence. The latter reason is groundless if the wiring is properly done, and the former is also of small moment, as but little high-tension current is installed

where there is liability of its being touched by persons who are not used to handling it.

The following table gives some figures on the cost of generating electric power. The costs are based upon the kilowatt-hour, which is the practical unit used to designate power, it being equal to 1·34 horse-power-hours. The cost is based, in most cases, upon the power delivered to the feeders that carry the current to the point of application. The cost for lighting and for power is usually different, as the power used for motors does not need such careful regulation of the pressure, and again the amount is usually large as compared with the amount sold for lighting, so that the cost to produce is less per unit and the amount is not so variable, hence the machines can be run at better efficiency.

The cost also depends upon the load factor of the plant; that is, upon the ratio of the average to the maximum output of the station, and the cost increases as this factor decreases.

COST OF ELECTRIC POWER.

Place and Use.	Cost K. W. Hour, Cts.	Authority.
Cheltenham, Eng., lighting	5.06	Lond., *E. Rev.*, Jan. 4, 1901.
Dundee, " "	4.90	" " "
London, price sold, "	5.00	" *E. Eng.*, "
" " " motors	5.00	" " "
Estimate operating expense	.58	Humphrey, *Lond. Eng.*, Jan. 4, 1901. These seven are for the operating expenses only.
Lighting, .5 load factor	1.02	
Mfg. works, large	.92	
" " fairly constant	1.23	
" " small, "	2.60	
Ord. " varying load	1.92	
Small " " "	3.60	
Dudley, Eng., selling price	4 00	*E. W.*, Feb. 2, 1901, for tramways.
" " " "	10.00	Other uses.
Average for United Kingdom	5.34	Garcke, *E. W.*, Jan. 26, 1901.
American, practice, range 3.00 to	7.5	Bolton, A.S.M.E., 20–873.
Met. El. Ry., Chicago, op. expenses,	.88	*E. R.*, Feb. 15, 1901.
Glasgow, Scotland, " "	2.56	B.I.E.E.
Lighting, to get to customer	3.56	Field, *Cass. Mag.*, Mar., 1896.
Railway, operating expenses	.90	
" large, at bus-bars	1.00	Kennelly, *Cass. Mag.*, 13–531.
" " op. expenses	.50	
Niagara power in Buffalo	2·00	

Place and Use.	Cost K. W. Hours, Cts.	Authority.
Railway, estimated, 33 per cent. L. F.,	1.00	Conant, *S. R. J.*, 14-621.
Kansas City, op. expenses	.40	" " 14-71.
Average at board	8.00	Editorial, " 14-92.
Brooklyn Heights, op. exp.	.62	
Denver Ry.	1.10	*E. W.*, Feb. 26, 1901.
" motor work	4.00	
Kansas City, Ry. op. exp., 1899	.43	*W. E.*, Oct. 20, 1900.
" " " " " 1900	.41	
Met. St. Ry., New York, 1898	1.57	*St. Ry. Jour.*, Nov., 1898.
Estimate at bus bars	.50	Bell, "El. Trans. of Power."

From the above table it may be seen that the cost of generating power is extremely variable in the different cases, depending upon the purpose for which it is used, the load-factor, the cost of fuel and the size of plant. For the case of large plants run by compound-condensing engines, with generators directly connected, operating under fairly good load-factors, it may be assumed that the cost of power per kilowatt at the bus-bars is not far from 1 cent, and it may be less with careful attendance. For water-power plants this figure may be lowered. The cost of distribution is so variable that no attempt has been made to estimate it, and it can only be approximated for specific cases.

The cost of electrical machinery depends upon the price of steel and copper to a large extent and so is variable, but may be assumed to range from $15 to $25 per kilowatt output for generators, motors or rotaries of the medium or large sizes. The price per unit increases as the size decreases, as they are less efficient and require more material and more labor in manufacture.

EFFICIENCY.

The efficiencies of electrical apparatus are usually very good, and range somewhere near the values given in the table below, which is for units of 100 horse-power or over, and applies to either direct or alternating current machinery.

	Per Cent.
Generators	90 to 96
Transformers	95 " 97
Transmission line	90 " 95
Rotaries	80 " 95
Motors	85 " 95

The above table is a fairly conservative one for this kind of machinery. For smaller units these values are too high, and in some cases of large machines operating under very good conditions they may be too low. The efficiency of transformers and synchronous motors with good power factors is very high and represents the limit of commercial machines.

The use of the storage battery is a great aid, in some cases, toward raising the efficiency of a power plant, for it allows the machines to be worked at their maximum efficiency and also relieves the prime mover from sudden variations of the load. This is especially noticeable in railway plants where the change of load is apt to be sudden, and also from a very small one to a very large one. Their use may take the place of an extra unit, which would only be used at the time of heavy load. The disadvantages of the storage battery are its high first cost, large repair and depreciation bills that come from its use, the extra amount of space they occupy, the extra cost involved in the purchase of a booster to be used in connection with them, so that they may be charged or discharged when the line pressure is different from that of the battery. Consequently, all things being considered, it is a question whether they are a paying investment.

The costs vary with the rate of discharge. If a battery has capacity enough to furnish 1,000 ampere-hours in one hour, and costs $80, then a battery to furnish the same number of ampere-hours at a discharge-rate of eight hours would cost $40. The cost is usually based upon a one-hour rate of discharge, and on the average may be assumed to be about $80 per kilowatt. This price includes switchboards and regulating devices.

LIGHTING.

The principal purposes for which electric power is used are lighting, traction, transmission, and power for driving shafting, or for other purposes where the steam-engine or other prime mover might be used. The subject of lighting will be treated first in respect to the relative efficiencies of

the different kinds of light, and then more especially in regard to the application of electricity.

Mr. J. Henderson, in an article in *Cassier's Magazine* for 1900, p. 336, gives a table of the commercial efficiencies of the various kinds of light; the commercial efficiency is that which is referred back to the coal, assuming that 1 pound of coal contains 11,000,000 feet pounds of energy and can yield about 4 cubic feet of gas at the lamp, representing 2,000,000 feet pounds of energy or an efficiency of 18 per cent., and in the case of the electric light, assuming the combined efficiency of boiler, engine and dynamo as 10 per cent., then the commercial efficiency of the lamps is as follows:

	Per Cent.
Bat's-wing burner	·23
Argand	·43
Incandescent lamp	·50
Arc lamp	1·30
Welsbach mantel	2·30

The luminous efficiency or the ratio of the light energy to the total energy radiated is given in the following table:

Source.	Efficiency. Per Cent.
Candle, ordinary wax	1·5
Bat's-wing gas burner	1·3
Oil lamp	2·0
Argand gas burner	2·4
Incandescent electric lamp	5·0
Lime light	9 to 14
Welsbach gas burner	13·0
Arc lamp	13·0
Magnesium ribbon	13·0
Electrical discharge in vacua	33·0
Sunlight	34·0

The efficiency of an electric lamp is usually stated at a certain number of watts per candle power. The ordinary arc lamp is more efficient than the incandescent. Some values given by Louis Bell, in his series of articles in the *Electrical World* for 1900–1901 for arc lamps, are: Arcs using clear outer globes and direct current, 2·89 watts per candle; similar alternating current arcs, 2·96 watts per candle; direct open-arc, 1 watt per mean spherical candle, and 1·3

for the same when shaded, while the same kind of lamps, using alternating current, required 1·7 and 2·2 watts per candle, respectively.

The following table gives some values of the power used for incandescent, arc and Nernst lamps gathered from various sources:

Authority.	Watts per Candle. Inc'd.	Arc.	Nernst.
Elect. World, Feb, 9, 1901	3·1–3·5		1·6–2·0
" " 31–811, hor. c. p.	3·25	3·45 d. c.	
" " " mean spherical . .	4·00	3·54 a. c.	
Wait, H. H., 450 watt, mean hor. c. p.		·80 d. c. 1·20 " enclosed. 1·60 a. c. "	
A.I.E.E., 14–425, two clear glass globes .		·50	
" " open inner, clear outer .		·58	
" " both opal		·95	
Nernst, Dg., *E. W.*, 37–609, direct cur. .		1·37	1·90
Bell, *E. W.*, Jan. 26, 1901			1·62

COST OF LIGHTING.

Authority.	Cost in Cents per C. P. Hour. Electric. Arc.	Inc'd.	Gas. Ord.	Welsbach.	Acetylene
E. W., 37–246	·053	·053 ·041			
Guy, *El. Light and Power* .	·013	·056	·026		
Prog. Age, Dec. 1, 1897 . .		·063	·039		
E. W., 29–523		·063	·031	·011	·004
" 30–672		·041	·055		
" 31–670	·006	·039	·044	·011	·031
Eng. Mag., 4–241		·200	·162		
Jacobus, *J. F. I.*, 97–364. . .	·063	·061	·011	·011	·031

From the above tables it may be seen that the electric light is not the cheapest, the Welsbach burner and the acetylene light being much cheaper, while the ordinary bat's-wing burner is a close competitor with the incandescent lamp. The arc lamp is considerably cheaper than the incandescent, but is not used to any very great extent for the lighting of residences, etc., as it is not made in very small sizes, but it is being used more and more at the present time since the introduction of the enclosed forms of direct and alternating current lamps.

The great advantages of the electric lamps over the others lie in the fact that they do not vitiate the air of the

rooms which they light, and also give a light of such a color that it is not tiring to the eyes. It is very easily controlled, and by the use of the regulating or dimming sockets that are coming into use may be turned down in the same way that gas or acetylene is, so that a less amount of light and consequently, of power consumed, may be used as needed.

The Welsbach burner and the acetylene light both have the same disadvantage of producing a light that is very white and tiring to the eyes, while the incandescent lamp gives a light more the color of sunlight.

The use of alternating current lighting is perhaps the most common at the present time, although the Edison three-wire system is extensively used in the large cities where the population is dense and the line loss would not be excessive. The employment of high pressures on the line and the use of transformers to step down the voltage to such values that it can be safely used in houses is the general system at the present time. The alternating current can also be transmitted for long distances with but little loss, which is an important factor in a great many cases.

On account of the above facts, it is very doubtful if any other source of light will be developed that will supersede it for general use.

TRACTION.

The subject of traction is a very important one at the present time, especially in the large cities and in the suburban districts lying near them. For the power, in these cases, there are several kinds that may be used—electricity, steam, cable, compressed air or animal power. Of these, perhaps, the one most used at the present time is electricity.

The subject of electrical traction will be treated first, as it is the most important, and the following table may serve to show how much power is required by street cars. These are the results obtained by tests, and are expressed in kilowatt hours per car mile:

STREET-CAR TESTS.

Road, Equipment.	K. W. Hours per Car Mile.	Authority.
Met. Elev., Chicago, Sprague system . .	1·32	Gerry, A.I.E.E., 14–353.
" " " 4 car train .	1·36	
" " " " " .	1·32	
" " " 3 " " .	1·69	
" " " 3 " " .	1·62	
" " " 2 " " .	1·58	
" " " 2 " " .	1·76	
" " " 4 " " .	1·11	
Lake St. "L," Chicago, G. E. No. 55 motor, 3 car train with 4 motors per car,	1·46	Chapman, *S. R. J.*, Oct., 1899.
Lake St. "L," Chicago, G. E. No. 51 B,	1·65	
Camden, N. J., 2 No. 38B mo., 50 H. P.,	1·97	*St. Ry. Jour.*, Nov., 1900.
" 2 No. 3 West. 30 "	1·47	
" 2 No. 5 Walker " "	·78	
" 1 No. 3 West. " "	1·00	
" 2 No. 49 35 "	1·26	
" 2 No. 33 West. 30 "	·79	

From the above table it may be seen that for the average case about 1·5 kilowatt hours per car mile are required for traction under the average city conditions. This is dependent upon the number of stops, the grades that have to be overcome, the efficiency of the motors, and also upon the way in which the motorman handles his controller and the speed that has to be made.

The cost of traction by different kinds of power is compared in the following table which gives the cost of operation per car mile of the various kinds. The column headed "Air" is for compressed air cars in which the air is held in tanks and then passed through reducing valves which reduce the pressure from about 2,000 pounds per square inch to about 150 pounds, after which it is reheated and passed through the motors which are similar to steam-engines in many respects. The electric cars are ordinary trolley or under-ground conduit system and the cable cars are the usual form of cable.

OPERATING EXPENSES OF STREET-CARS.

Authority, Remarks.	Operating Expenses, Cts. per C. M. Air.	Horse.	Cable.	Elect.
S. R. J., 14–65, Godfernaux	13.50			10.00
Jour. F. Inst., June, 1899	12.00			

Authority, Remarks.	Operating Expenses, Cts. per C. M. Air.	Horse.	Cable.	Elect.
S. R. J, 14–104, Chicago City, '97		24.10	10.71	13.05
" 15–580 " " '98		27.20	10.80	12.90
" " Met. St. Ry., N. Y. '98		11.96	18.00	11.95
" Oct., 1898, Conant (estimate)				9.50
" 15–51, 10 Mass. Report Com., 1900 . . .				16.10
Report Conn. R. R. Com., 1898				12.71
" N. Y. R. R. Com., 1900, av. of 26 roads .				11.90
S. R. J., 16–43, Met. St. Ry., 1900	17.42	18.98	17.76	13.16

From the above it may be seen that the operating expense is variable and depends upon so many factors that it is impossible to get an average value, but the range may be indicated by the above figures.

The efficiencies of the different kinds of power used in traction vary to a great extent. The average efficiency of the electrical system from the indicated power of the engine to the car axle may be assumed to be about 50 per cent. Mr. Martin in a paper before the A.I.E.E. 4–26, gives the efficiency of the cable system in Kansas City as 25 per cent., in Chicago as 18·5 per cent. and in San Francisco as 33 per cent. From these figures it may be seen that the electric system is much more efficient, but in some cases the cable is cheaper in operating expenses than the electric.

TRANSMISSION.

The subject of transmission of power is a very important one at the present time. For this purpose, the electric current has no competitors for long distances as high potential alternating currents may be used with but a small loss in transmission. There are, however, different means of transmitting power for shorter distances, that are being used at the present time more or less. These are hydraulic, in which water under high pressure is conveyed in pipes and used in water-motors of different models, usually some form of the tangential or impulse wheel, pneumatic in which air under pressure is carried in pipes and used in motors which are similar to steam-engines and the use of belting or ropes or cables. The latter has been almost universally used in shops and factories where a large number of small machines were to be driven and for transmission from one building

to another. The use of compressed air has been used for air drills and for small power units, especially in contracting work and in mines where the exhaust air is needed for ventilating purposes. The hydraulic system is not used to any very great extent in the United States, but is used in London, in which city there is quite a large business. The electrical system is coming rapidly into use in factories and shops, either being used with motors directly connected to the different machines or a part of the shafting being driven by larger motors. The great advantage of this system is, that the loss is proportional to the load, while the loss by belting or shafting is constant, and although it may be small in proportion to the total power at full load, yet it is the same at light load, and is then much larger as compared to the load, and the efficiency is consequently lessened.

The following figures have been collected to show the relative efficiencies of the different methods of transmission for comparatively short distances. This table is from *Trans. A.I.E.E.* 18–412, computed by Wm. Geipel, of Edinburgh, and shows the first cost of plants per horse-power transmitted.

System.	Distance Transmitted, Yards.			
	100	1,100	11,000	22,000
Electrical	$155	$170	$286	$423
Hydraulic	68	186	800	1,510
Pneumatic	126	165	530	935
Wire rope	5	41	393	787

These values are proportional to the fixed charges.

The following table gives the relative efficiencies from input to output of the various methods and may be taken as representing average cases.

EFFICIENCIES.

Authority, Remarks.	Efficiency, Per Cent. El.	Hyd.	Pneu.	Rope.
Bell, "El. Transmission of Power," full load, high press. water, air not reheated	73	53	66	56
Bell, low press. water, air reheated		50	65	
" half load, same as first	65	45	40	46
" " " " " second		50	50	
West. Electrician, Oct., 27, 1900	74			
Unwin, *Cassier's Mag.*, 1–449, air cold		40–50		
" " " " " reheated		59–73		

Authority, Remarks.		Efficiency, Per Cent. El.	Hyd.	Pneu.	Rope.
Unwin, Same, 20,000 H. P., 20 miles, 133 lbs. press. . . .				88 (estimate)	
Telluride, Col., 120 H. P., 2·75 miles		75			
Pomona, Cal., A.I.E.E., 12–403, 42·5 miles		63			
Bell, *Eng. Mag.*, Jan., 1901, 1,000 H. P.		70		50	
Adams, " 18–837		73			
Beringer, *Cass. Mag.*, 1–449, estimated	.5 mi. . .		50	55	91
	1 " . .		49	54	85
	3 " . .		41	51	61
	5 " . .		37	50	43
	10 " . .		26	43	21
	15 " . .		18	39	11

The above table may serve to show the difference in the relative efficiencies of the different methods. The highest is for electrical transmission, except for short distances, in which case the rope or belt-drive has the advantage, but its efficiency falls off rapidly as the distance increases. The electric system may be made very efficient by using high pressures and by putting in sufficient copper in the line to prevent loss due to the resistance of the conductor. There is a point where the fixed charges due to increase of copper overbalance the saving caused by such extra copper. If it is safe to assume that the efficiency of an electrical line can be made 90 per cent., and if the motors and generators are 85 per cent., then the total efficiency is 65 per cent. from the input of the generator to the output of the motor. The compressed-air system is very good in so far as the losses in transmission are concerned, but the principal losses are those in the motors, especially if the air is not reheated before being used in them.

Mr. Kennedy, in an article in the *Eng. Mag.* 3–585, says that a plant in Paris has an efficiency of 50 per cent. from the indicated horse-power of the compressor to the indicated horse-power of the motor when the air is reheated, the distance being four miles. Professor Saunders, in the *Journal of the Franklin Institute*, May, 1862, says, that for common machinery and no reheating the efficiency is about 30 per cent., best compressor and no reheating 40 per cent., and for the best machinery and reheated air the efficiency may be as high as 80 per cent.

In this connection, the use of electricity in shops and factories, in the place of belts and shafting, may be treated. As has been mentioned before, the loss in the electrical system is nearly proportional to the load, while the loss by belts and shafting is constant for all loads. The following table may serve to show the efficiencies that may be expected of shafting and belts:

Authority, Remarks.	Efficiency Per Cent.
Henthorn, A.S.M.E., 16–462, average practice	50–55
" " " 50 cotton or woolen mills	74
Barrus, " " 8 mills	78
Lufkin, *Cass. Mag.*, 5–369, av. of 30 tests in 1890	32
Benjamin, " 17–215, machine shops, average	45
Flather, *Eng. Mag.*, 8–670, average of 9 shops	60
Scott, "El. Power in Workshops," av. 319 French shops	60
Hutton, *Eng. Mag.*, Jan., 1901	60–80
Bell, " " wood and metal working	50–80
Lond. *El. Review*, Jan. 11, 1901, heavy machine work	55
" " " 8 factories in U. S. A.	56
Benjamin, A.S.M.E., 18–230, 3 cases, full load	56
" " " 6 " half "	45

These values are for the ratio of power taken from the shaft of the machines to that put into the main-line shaft at the engine and includes only the loss in belts and shafts.

The losses in the electric system are less than in the other. The following table may serve to show what efficiency can be obtained by the use of motors directly connected to the machines:

Authority, Remarks.	Efficiency. Per Cent.
Elect. World, Feb. 16, 1901	73
Engineer (N. Y.) Jan. 1901, 300 H. P.	71
West. Elect., Mar. 16, 1901	62
Louis Bell, *Eng. Mag.*, Jan., 1901, not over 5 per cent. drop on ·5 load	75–80
Lond. *El. Rev.*, Jan. 11, 1901	81
Richmond, *Eng. Mag.*, 8–669, ordinary cases	50
" " " more favorable conditions	73
Anthony, " " estimate, 1 to 5 H. P. motors	70

The above shows that a fair average efficiency is about 70 per cent. for good systems, and is about 10 per cent. or 15 per cent. higher than can be expected from shafting and belts.

The table below, taken from E. K. Scott's "Electric Power in Workshops," shows the relative efficiencies of the two systems for different loads, and is estimated, with all the losses taken into account, both mechanical and electrical. It is from the developed power of the engine to the power available at the machine, and is for a 1,000 horse-power engine. The constant loss in the belting and shafting is 206 horse-power for the case of the belt drive.

This table was calculated by M. Felix Mélotte. The table has a great many items that are omitted here, but the main ones are given below. All figures are in horse-power.

Horse-power, per, by engine	1,000	750	500	250	200
Constant friction loss	50	50	50	50	50
Variable elect. loss	50	27	11	4·5	1·2
Total loss in dynamo	100	77	61	52·2	51·2
Loss in conductors	18	10	4	·8	·5
Loss in motor	88	73	61·5	54·7	53·1
Power available at machine	794	590	373·5	142·3	94·5
Total efficiency, per cent.	79·4	87·7	74·7	57·0	47·2

SAME FOR MECHANICAL TRANSMISSION.

Loss in shafting and belts, constant at 200 horse-power.

Power available at machine	794	544	294	44	0
Total efficiency, per cent.	79·4	72·5	58·8	38·1	0

From the above it may be seen that the two systems are about the same in efficiency for full load, but the falling off of efficiency for lighter loads is much more rapid in the case of the shafting. This is a very important item, especially for machine shops which have variable loads, and is not so much so for cotton mills or other factories that have constant loads.

THE SAND BLAST FOR CLEANSING STRUCTURAL IRON WORK.

The best means of protecting structural iron work, such as railway stations, bridges, escapes, due to the action of the elements and to the corrosive influences of the gases emitted from locomotives, have been earnestly sought by engineers, and there is yet much diversity of opinion among them on the subject. Thus far the only method pursued is that of systematically keeping the iron work of these and similar structures protected by repeated applications of paint, the material used for the purpose being either oxide of iron or red lead in linseed oil. The deterioration of these coatings, however, is so rapid that constant watchfulness is required to keep the metal beneath free

from rusting. The trouble arises partly from the gradual cracking of the paint film which allows the penetration of moisture and corrosive gases to the metal surface, causing the formation of rust and the lessening of the adherence of the paint, and partly to chemical changes in the paint film itself by the absorption of sulphurous gases. From these causes principally the frequent renewal of paint on exposed iron structures is found to be a necessity to preserve their integrity, and the nominal cost of this sort of work to the railroad companies is a very considerable item. Numerous investigations have been undertaken with the view of finding some substitute for the paints and oils usually employed for the purpose, or to secure their better adherence and greater durability, but thus far without substantial results.

The overhead iron work of one of the stations of the Manhattan Elevated Railroad in New York affords a conspicuous example of what has been stated. It was found that the metal of this structure is so strongly and rapidly corroded by the sulphurous gases of the locomotives that the yearly renewal of the paint with which it was coated was insufficient to preserve it. It was accordingly determined to make an exhaustive series of trials of the most approved paint compositions that could be found in the market. Some eighteen different compositions were applied to different portions of the structure, and their effects as protective coverings are to be closely observed.

The specially interesting feature of these trials, however, is the fact that the sand-blast was used for the purpose of removing the old paint and thoroughly scouring the metal before applying the new coatings. The object of this preliminary treatment was to obtain a clean metallic surface, to which the paint would adhere as perfectly as possible. The result of this operation has thus far not been made public. W.

PIVOTED OR SWINGING WINDOWS.

The city of Chicago has enacted a building ordinance requiring that on all new buildings there shall be swinging windows above the second story. The object sought to be accomplished by this enactment is to prevent the accidents in washing windows which are of common occurrence.

The ordinance specifies that the window must swing on four vertical or horizontal pivots, or otherwise a balcony must be built around every window. It is said that the local architects and builders object to the law. W.

ZINC BY ELECTROLYSIS.

Electrical Review is responsible for the statement that the extraction of zinc from its ores by electrolytic methods has been attempted at Hayle, in Cornwall, and at Milton, in Staffordshire. At the first-named place a leaching process, patented by Cowper-Coles, was operated with indifferent results, and the experimental plant is now shut down. At Milton the Swinburne-Ashcroft fusion process has been under trial by the Phœnix Process Syndicate with fairly satisfactory results. The inventors believe that with slight modifications this process will solve the problem of winning all the metals contained in the mixed sulphide ores.

The experimental trials of this process have been transferred to Weston Point, and the Milton works have now been dismantled. W.

Mining and Metallurgical Section.

Stated Meeting held April 10, 1901.

THE INSPECTION AND TESTING OF CEMENTS.

BY RICHARD L. HUMPHREY,
Member of the Institute.

The subject upon which I shall claim your attention this evening may be comparatively new to some, familiar to many, and a very old, old story to others.

After nearly ten years' experience in the inspection and testing of cements, I feel that I am in a measure qualified to speak on the subject, and if I am able so to present the matter as to enlighten any in this audience, I shall feel that the effort has been justified.

The testing of cements has been engaging the attention of engineers and cement manufacturers for many years, and as yet no entirely satisfactory system has been proposed which will eliminate the personal equation of those who make the tests, a variation which renders the results of such tests not only relative but inaccurate.

The endeavor to secure methods or appliances by which the personal equation is reduced to a minimum is of paramount importance to those upon whom devolves the task of making the tests, which determine the value of cements for constructive purposes.

The inspecting and testing of cements is an art requiring much skill and considerable experience. Of the materials of construction, cement is one of the most difficult to test, and to interpret the results obtained.

From the moment the clinker is reduced to an impalpable powder, its physical and chemical properties are constantly undergoing changes which affect its quality and value as a building material.

Even after the cement has been made into a mortar and become a part of the structure, these changes continue, being to a greater or less extent effected by external influ-

ences tending to decompose the mortar, or by internal influences tending either to disintegrate the mass or accelerate the process of crystallization usually known as hardening. Indeed, it is probably true that these influences never cease. The strength and quality of the material during this period is an unknown factor, and our knowledge as to the exact nature of these changes is purely theoretical. Much research will be required in order to be able to state just what these changes are.

The ancient Romans and others had learned by experience that mixtures of fat lime and volcanic ash when made into a mortar upon the addition of water, possessed the property of hardening and acquiring some strength, and were, therefore, adapted for building purposes.

It was at first thought that the strength of the mortar was dependent on the absorption of carbonic-acid gas from the air, which, reacting on the lime, formed a hard carbonate. Later researches have shown, however, that only the outer surface was converted into carbonate of lime, and that this carbonization after many years did not extend more than one-eighth of an inch below the surface of the mortar.

Another theory advanced was, that the volcanic ash contained silica in a soluble form which reacted on the hydrate of lime to form a silicate of lime. It has been shown that only the outer surface of each grain of silica has been converted into silicate of lime.

It is probably true that the lime, upon the addition of water, was converted into a hydrate, and that the formation of carbonate of lime, by the absorption of carbonic-acid gas from the air, acted as a protection against the action of rains and other forces of nature tending to dissolve and wash out the hydrate of lime.

Lime mortar and mixtures of slacked lime and puzzolanas or trass continued to be the building material until the close of the eighteenth century.

This material made a very poor mortar and numerous experiments were made to discover something more durable.

Dr. Higgins, an English writer, in reporting the results of his experiments on calcareous cements and quicklime, published about 1780, complains that the "strength and duration" of their most "useful and expensive buildings depends on the goodness of the mortar, which is commonly so bad that the timbers of the buildings last longer than the walls unless the mouldering cement be frequently replaced by pointing."

The object of his experiment was to "recover or to excel the Roman cement which had withstood every trial of 1,500 or 2,000 years."

In 1756, Smeaton, in rebuilding the Eddystone Lighthouse, experimented with various limestones and mixtures of slacked lime, dutch trass and puzzolanas, in his endeavor to find a material that would harden under water. He finally found that a mixture of slacked lime and puzzolanas attained the greatest hardness under water.

Parker, in 1795, took out a patent for a water cement, and, in 1824, John Aspdin, a Leeds bricklayer, took out letters patent for a material which he called "Portland Cement," on account of its resemblance to the building stone coming from the Isle of Portland, off the coast of England.

Prior to this period the endeavor was to equal or excel the Roman cement, which was produced by grinding calcined septaria nodules. This cement corresponded to a class of natural cements in this country, commonly known as "Rosendale," "Lehigh," "Cumberland," "Louisville" "Utica," etc. The development of the cement industry began shortly after the granting of the patent of Aspdin, starting in England and spreading gradually into France, Germany and other European countries. Natural cement was first made in this country in 1818 by Canvass White, and was used largely in the construction of the Erie Canal.

It is noticeable that nearly all the early natural cement factories were located along the banks of canals and that the product of these factories was used in their construction. Thus we find that the cement made at Rosendale, Ulster County, N. Y., was used in the construction of the

Delaware and Hudson Canal; the cement manufactured at Louisville, Ky., in the Louisville and Portland Canal; that made at Round Top, Md., in the Chesapeake and Ohio Canal; the Illinois and Michigan Canal was built with cement made at Utica, Ill.; while the cement made at Siegfried's Bridge, Pa., was used in the Lehigh Coal and Navigation Company's Canal.

The total production of natural cement up to 1830 amounted to 300,000 barrels; since then it has grown steadily until in 1900 it amounted to over 10,000,000 barrels.

In this country, since 1890, the development has been principally in the manufacture of Portland Cement. The production increasing from 400,000 barrels per annum in 1890, to over 8,000,000 barrels per annum in 1900.

DEVELOPMENT OF METHODS.

Smeaton, in order to determine the value of his various cements, made them into balls and immersed them in water, thus establishing their hydraulic qualities.

Vicat, in his celebrated book, entitled "Experimental Researches on the Limes of Construction, Concretes and Ordinary Mortars," in order to determine the relative value of mortars, devised an apparatus which bears his name, and which has been modified, and is now used in determining the time of setting. Vicat's test was to allow a needle loaded with a given weight to fall a given distance into the mortar. The amount of this penetration was measured; the amount of penetration being proportional to the hardness. (Plate I.)

Prior to the experiments of Colonel C. W. Pasley, in 1830, a common method for testing the cementitious value of limes and cement, was to stick bricks together with it, one at a time, projecting horizontally from a wall. That lime or cement was considered the strongest which held the greatest number of bricks. In this test no distinction was made between quick and slow setting cements. (Plate II, *Fig. 1.*)

A similar practice was in vogue in the city of Philadelphia for a number of years. Inspectors on the work satis-

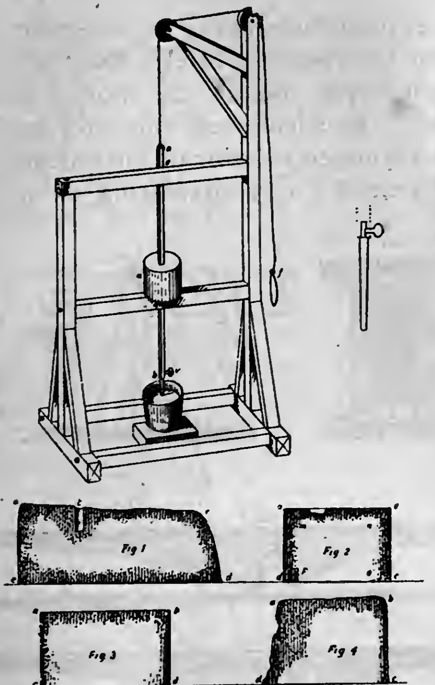

PLATE I—Vicat needle, as originally designed.

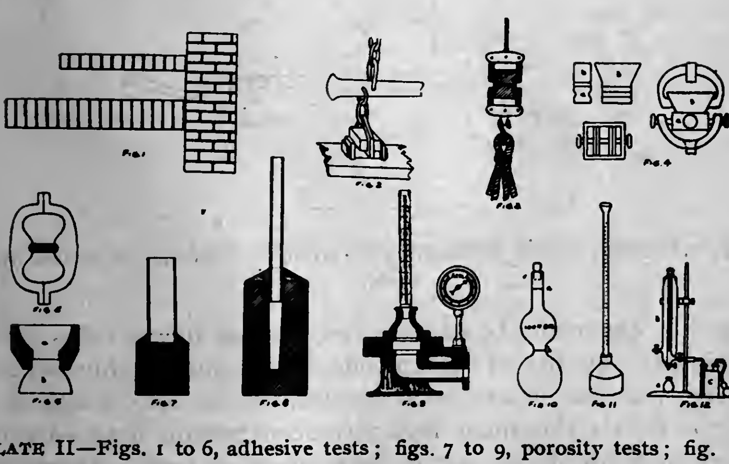

PLATE II—Figs. 1 to 6, adhesive tests; figs. 7 to 9, porosity tests; fig. 10, Keate's specific gravity flask; fig. 11, Schumann's volumenometer; fig. 12, Erdmenger volumenometer.

fied themselves as to the quality of a cement by placing a layer of mortar between two bricks; the test was to observe the time which elapsed before the mortar would hold the bricks together. By such a test the slow-setting Portland cements were adjudged inferior to the quick-setting natural cements. It is exceedingly interesting to note that Pasley

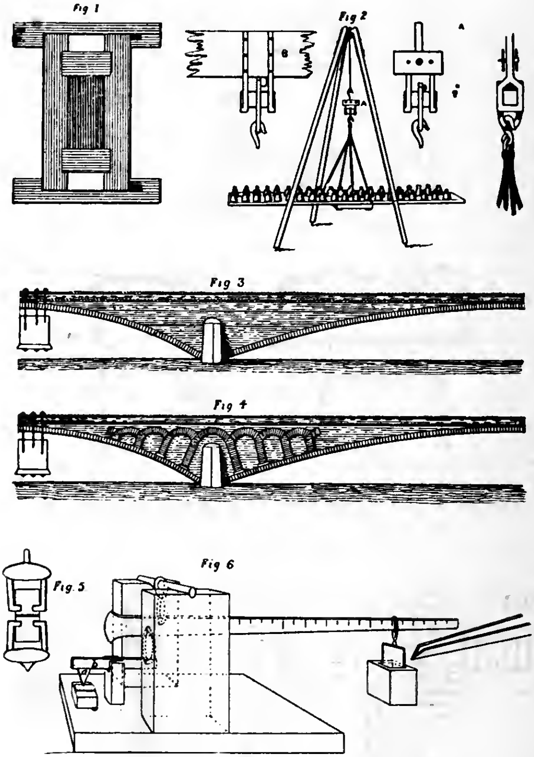

PLATE III—Apparatus for determining the strength of mortars as devised by Pasley.

from his experiments endeavored "to lay down rules for judging the quality of cement offered for sale and for ascertaining whether it has been adulterated or not, by attending to which the most inexperienced person may easily detect such frauds in twenty-four hours, or less." In view of our present difficulties and troubles in securing uniformly

accurate tests, his claim that "rules have been laid down by which their comparative strength may be judged of experimentally, and in a short space of time, such as ten days, with very little trouble, and the greatest accuracy," appears very amusing.

Pasley, in his experiments, tested cement by sticking two bricks together with the mortar, and after allowing them

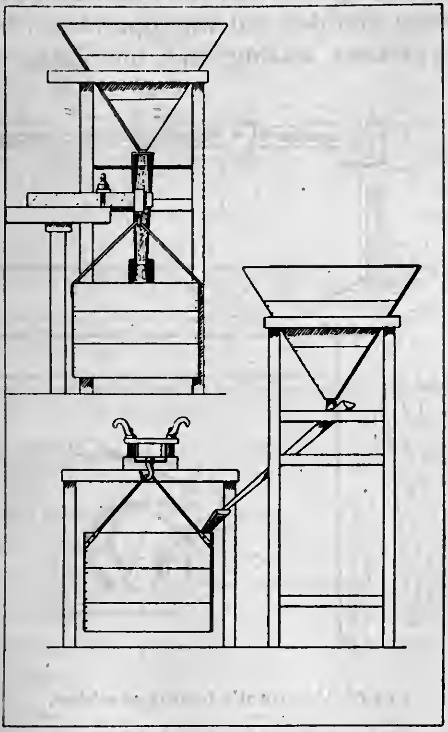

PLATE IV—Early testing apparatus—mortar tested by flexure.

to harden for a certain time, he suspended them from a tripod, by a pair of nippers or clamps, fixed on the upper brick, and placing a similar pair of nippers or clamps on the lower brick, attached weighs thereto, and determined the weight required to pull the bricks apart. He also ascertained the time required for the cement to harden under water. (See Plate III.)

In 1858, John Grant, engineer for the Metropolitan Board of Works, in connection with the London Drainage Works, began his well-known tests of cement. He was the first to develop definite methods for testing cement. He devised a machine for determining the tensile strength of cement after which the present Olsen and Riehlé machines are patterned. (Plate V.)

Later, Henry Faija showed the importance of the soundness of a cement and devised an apparatus which bears his name. The present boiling and hot-water tests are but

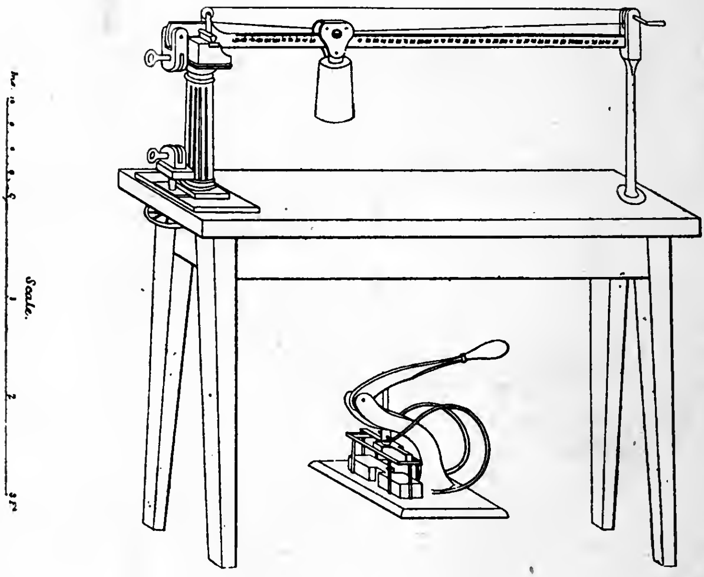

PLATE V—Grant's testing machine.

modifications of his method. (Plate XX, *Fig. 1.*) He also devised a short-lever machine for determining the tensile strength. Michaelis also devised a similar machine to which the Fairbanks machine owes its origin. It is interesting to note that Faija did not believe in the utility of the sand test, maintaining that it first involved testing the sand and was, therefore, valueless as a comparative test unless the same quality of sand could also be guaranteed. (Plates XIII and XIV.)

The development of the methods of testing came slowly after Grant had set the pace, and Faija and Michaelis had improved and added to them. The Committee of the American Society of Civil Engineers, in 1885, formulated the rules which have been in vogue in this country, and have been generally accepted as the standard. These rules have well served their purpose, but are now, however, deficient in many respects, notably in that which defines the normal consistency to be "a stiff plastic paste." The normal consistency is the most important factor in our present methods of testing.

A great deal of work has been done in the development of methods of tests, notably by the German Association of Cement Manufacturers; by the Commission appointed by the French Government in 1891, whose voluminous report may be regarded as a standard reference, and also by the various conferences of the International Association for Testing Materials.

In 1899, the American Society of Civil Engineers appointed a new committee to report on "the proper manipulation of tests of cement." It is highly probable that this committee will not only bring the old rules up to date, but will also define a system to be used. This embraces, in a brief, general way, the history of the development of the methods for testing cement.

The object of testing cement is two-fold: (1) To ascertain its value as a building material by determining whether the cement meets certain specified requirements; and (2) for scientific purposes.

SPECIFICATIONS.

The first requisite in any system of inspection is a standard by which to gauge the quality of the material. This standard is usually established by each engineer to suit his conditions. In establishing this standard the engineer will save himself needless trouble by first selecting, wherever possible, some one who will make the tests and ascertain what tests he is able to secure from well known brands of cement, and then fix his requirements in accordance with

these results. As the cement inspector acquires greater skill in making the tests, and is, therefore, able to obtain higher results from cement, this standard can be raised. The present high standard of the city of Philadelphia is the gradual development from such a system.*

INSPECTING AND SAMPLING.

On account of the changes which take place in the quality of the cement, from the time it leaves the factory until it is delivered at the point of consumption, it is customary to inspect the cement on the work in which it is to be used; although it is true that in some important engineering works it has lately been the practice to inspect the cement at the place of manufacture. Each shipment of accepted cement is marked by the inspector.

This method avoids extra handling of the cement in case it is not up to the prescribed standard, since the inspector can select from the various bins at the factory the cement required. It is also the custom to make check tests upon the arrival of this cement at the place of consumption.

Cement is usually shipped in cotton sacks or paper bags, although about 25 per cent. of the shipments are in wood. Where cement is going to be used immediately and will not be held long in storage, the bag shipments are undoubtedly more convenient and satisfactory, besides being more easily handled on the work. Such shipments can also be sampled much more thoroughly. Cement was shipped in barrels in this country in the early days, as it was generally accepted that cement must be kept in tight packages, as it deteriorated in the air; and besides nearly all the early natural-cement mills were located along canals, and the cement had to be placed in wooden packages for water shipments. Again, prior to 1893, foreign Portland cement was used very extensively in this country, and on account of the ocean voyage it was absolutely necessary to pack the cement in tight, well-coopered barrels in order to avoid damage to the cement from sea-water, and to the barrel from the handling

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* *Jour. Franklin Institute*, Vol. CXLVI, No. 5, p. 344.

it received in loading and unloading. When the American cements began to replace the foreign Portland cements the American engineers had become so accustomed to cement in barrels that they continued to insist on shipments of cement being delivered in wood. This sentiment is, however, undergoing a change, and bag shipments are becoming the rule. Another advantage of having cement delivered in sacks is the reduced cost of the package.

The danger of inferior cement being rebagged is readily avoided by requiring the cement manufacturer to seal his bags with a lead seal, such as is the custom in France and other foreign countries. The packages should state plainly the brand, name and place of manufacture, and all shipments of cement which are not properly labelled should not be inspected.

Shipments of cement are usually made in carload lots of 100 barrels each, although in some cases a shipment will contain 150 barrels; it is convenient, therefore, to inspect cement in carload lots, particularly where there is a large amount of cement entering into the structure.

In selecting the sample for testing a note should be made of the general condition of the shipment; that is, whether the cement is caked, lumpy, or otherwise damaged, as, in many cases, owing to improper protection, the shipment is damaged pending the tests.

The test sample should be taken from the heart of each package, since the quality of the cement on the outer portion of the package is sometimes more or less impaired. The jarring the package receives in transportation over the railroad has a tendency to separate the coarse from the fine particles. Where the cement is delivered in barrels, the sample is drawn from the center by making a hole in the center of one of the staves, midway between the heads, and collecting this sample through the hole by means of a scoop. In bag shipments the sample can be extracted by means of the hand or a scoop. In barrel shipments a sample should be taken from one barrel in every ten; and in bag shipments a sample should be taken from one bag

in every twenty. About one-half pint should be taken from each package in barrel shipments, and about half this quantity in bag shipments. Well-established brands of cement should ordinarily be accepted on the results of the "seven days' tests."

In case of failure of the shipment to meet the seven-day requirements, it should be held to await the results of the twenty-eight day tests. Care should be taken to see that shipments of cement, while awaiting the result of the tests, are thoroughly protected from the weather; the cement should be well housed and carefully blocked from the ground. I have known instances where cement which met the requirements, through the lack of protection during the tests, had become so badly damaged as to render it unfit for use. Under such circumstances it would be unsafe to use the cement, and yet it would be a decided injustice to both manufacturer and contractor to hold the cement for a retest. Such complications could be avoided by insisting that the cement be properly housed and protected before inspecting it.

Where sampling cans are used, containing several compartments, care should be observed to mark each compartment so that the samples cannot be confused. It is best to number the compartment on the can, and make a record of the sample at the time of collection. (See Plate 6, *Fig. 10.*) The ten or twenty individual samples which comprise the general sample should be thoroughly mixed before attempting to make any tests. This is best accomplished by passing the sample through a coarse sieve, either a No. 20 or No. 30. This not only thoroughly mixes the sample, but also removes sticks, stones or other foreign matter.

The tests which should be made will depend on the importance of the work and the facilities for making them. The simplest methods, as a rule, yield the most uniform tests; and the uniformity of the tests is a matter of prime importance.

I am not in favor of any system which depends on cumbersome methods or expensive apparatus. The number of tests required should be few, and simple in execution.

Tests are made for the purpose of establishing the qualities of a cement—uniformity of composition and burning, fineness, soundness and strength.

CHEMICAL ANALYSIS.

Systematic chemical analyses of cement should be made in all permanent laboratories; not with a view of eventually introducing into specifications chemical requirements (other than those for sulphuric acid and possibly magnesia), but in order that we may have some data pertaining to the composition of the cement when studying the results of the long-time tests.

When, however, they are required on the work, the sample should be sent to a well-established chemical laboratory having proper facilities for accurate work, as such analyses should be made only by a skilled chemist.

I have used the following scheme of chemical analyses with excellent results:

One-half gram of the finely pulverized sample, dried at 100° C., is thoroughly mixed with four or five times its weight of sodium carbonate and fused in a platinum crucible until CO_2 no longer escapes; the crucible and its contents is placed in a beaker and twenty or thirty times its quantity of water, and about 10 cubic centimeters of dilute HCl is added; when complete solution is effected, it is transferred to a casserole, placed on a water bath, and evaporated to dryness several times. The mass is taken up with dilute HCl and water, heated for a short time and filtered, washing the residue on the filter thoroughly with hot water. The filter is dried, ignited and weighed. This weight (less ash) gives the amount SiO_2.

The filtrate is brought to boiling, and ammonia is added in slight excess; the boiling is continued until the odor of ammonia is no longer perceptible. Filter and wash re-dissolved in hot dilute HCl, again precipitate with ammonia and filter through the previous filter and wash with boiling water. The precipitate dried, ignited and weighed, less ash, gives the amount of Al_2O_3 and Fe_2O_3.

The iron is determined volumetrically by fusing the

ignited precipitates of alumina and iron with de-dydrated potassium sulphate in the platinum crucible; it is then dissolved in sulphuric acid and tirated with potassium permanganate.

The filtrate from the iron and alumina is heated to boiling, and boiling ammoniam oxalate is added until a precipitate is no longer formed. After boiling for a few minutes, it is set aside for a short time; when the precipitate has settled perfectly, decant the clear liquid through a filter, wash by decantation, dissolve the precipitate in hot dilute HCl, using as small a quantity as possible to effect a complete solution; heat to boiling and add ammonia, heat on a water bath for a few minutes; when the solution clears filter through the previous filter, wash thoroughly with hot water. Dry the precipitate, ignite to constant weight, and weigh as CaO; or determine the lime volumetrically by titration with potassium permanganate.

The thoroughly washed precipitate of calcium oxalate is dissolved in hot dilute sulphuric acid and the solution is titrated with potassium permanganate.

The filtrate from the calcium oxalate is made alkaline with ammonia and 30 cubic centimeters of solution of hydrodisodium phosphate is added; the whole is set aside in a cool place for twenty-four hours; it is then filtered and washed about fifteen times with ammonia-water solution (1 : 5). Dry the precipitate on the filter, brush on to a large watch glass, burn filter on the lid of the weighed crucible. When the carbon is consumed, transfer the precipitate to the crucible and ignite to dull redness, keeping the crucible covered. If the precipitate is not perfectly white on cooling, moisten with a few drops of nitric acid, evaporate and ignite to dryness; weigh as magnesium pyrophosphate and calculate to MgO.

Sulphuric acid. This is determined in a separate portion. Weigh out about five grams and treat as in the regular analysis, separating the silica; the filtrate is heated to boiling and boiling barium chloride is added; the boiling is continued for ten minutes; when the precipitate has subsided, filter. The precipitate is thoroughly washed in

hot water, dried, ignited and weighed as barium sulphate and calculated to So_3.

Carbonic acid. This can be determined with sufficient accuracy by means of the ordinary extraction apparatus.

FINENESS.

The fineness to which the cement has been ground is usually measured by the percentage of residue on what are known as No. 50, No. 100 and No. 200 sieves, having approximately 2,500, 10,000 and 40,000 meshes per square inch. As it is impossible to obtain sieves of exactly this number of meshes the sieves should be definitely described; *i. e.*, the size of wire and actual number of meshes per square inch should be stated. The No. 50 sieve can be readily obtained; the No. 100 much less readily, while it is impossible to obtain a standard No. 200 sieve. The meshes in the cloth vary from 30,000 to 46,000 meshes per square inch.

The No. 50 sieve has no practical value, since all cements of good quality leave practically no residue on this sieve.

The sample for sieving should be thoroughly dried at a temperature of about 130° F, since in this condition the cement sieves much more readily. One hundred grams make a very convenient quantity to sieve.

The manner in which the sieving is done determines to a large extent the time required for the operation. After the fine flour has passed through the sieve the coarser particles pass through very slowly; and, since the final operation determines the fineness, it is important that it should be done thoroughly. I have, after considerable experiment, decided that the operation of sieving was for all practical purposes complete when not more than $\frac{1}{10}$ of 1 per cent. passes through the sieve after five minutes' continuous sieving.

Various mechanical devices have been devised for automatic sieving, but as far as my experience goes there is none that has proved satisfactory. The apparatus which is used in the laboratory of the city of Philadelphia works fairly well on some cements; with others, however, it is im-

possible to sieve them. Sieving by hand is by far the best method; in this case the most effective way is to move the sieve backwards and forwards in a slightly inclined position, and striking the sieve sharply and continuously with the palm of the hand. The number of strokes per minute should be about 200. The cloth of the sieve should be carefully watched, as it is liable to break and thus become defective, giving rise to incorrect and abnormal tests. The size of the sieve also effects the rate of sieving. A sieve 8 inches in diameter is a good size. Large pebbles, gravel, sand or shot which are retained on a No. 10 sieve are often placed in the sieve with the cement. This tends to accelerate the operation of sieving, but it is exceedingly hard on the cloth of the sieve, and for this reason is objectionable.

The methods for determining the fineness by elutriation and by air separation have not been sufficiently tried to enable an opinion as to their merits to be formed.

The former does not seem, however, to be adaptable for quick work. The latter merits further investigation, and it is not improbable that it will eventually supersede the unsatisfactory method by sieves.

SPECIFIC GRAVITY.

The true density or specific gravity of cement is of considerable value when properly used. I do not recommend the test, except for a permanent laboratory, since it is a test requiring skill and accuracy, and is, therefore, not adapted as an ordinary test of reception on the work.

Where the tests can be properly made, it is of considerable value in detecting adulterations, etc. Quite a number of appliances have been devised for making this test, among which may be mentioned Le Chatelier, Candlot, Mann, Schumann and Erdmenger. Of these Le Chatelier's is unquestionably the best, since it is the most convenient to use and less liable to error from retained air bubbles and leakage at the connections, as in the other forms.

Le Chatelier's Apparatus.—This apparatus consists of a flask *D* (Plate VI, *Fig. 3*) of 120 cubic centimeters capacity, the neck of which is about 20 centimeters long. In the middle of this

neck is a bulb *C*, above and below which are two marks engraved on the neck, the volume between these marks, *E* and *F*, being exactly 20 cubic centimeters. Above the bulb the neck is graduated into $\frac{1}{10}$ cubic centimeters. The neck has a diameter of 9 millimeters. Benzine, being free from water, and being neither very volatile nor hygroscopic, is used in making the determinations.

The specific gravity can be determined in two ways: (1) The flask is filled with benzine to the lower mark *E*, and 64 grams of powder are weighed out; the powder is carefully introduced into the flask by the aid of the funnel *B*. The stem of this funnel descends into the neck of the flask to a point a short distance below the upper mark. The cement cannot stick to the sides of the neck and obstruct its passage. As the level of the benzine approaches the upper mark, the powder is introduced carefully and in small quantities at a time until the upper mark is reached. The difference between the weight of the cement remaining and the weight of the original quantity (64 grams) is the volume which has displaced 20 cubic centimeters.

(2) The whole quantity of cement is introduced, and the level of the benzine rises to some division of the graduated neck. This reading + 20 cubic centimeters is the volume displaced by 64 grams of cement. The specific gravity is then obtained from the formula:

$$\text{Sp. gr.} = \frac{\text{Weight in air.}}{\text{Displaced weight or loss of weight in water.}}$$

The flask, during the operation, is kept immersed in water in a jar *A*, in order to avoid any possible error due to variations in the temperature of the benzine. The cement in falling through the long tube completely frees itself from all air bubbles. The results obtained agree within ·02.

TIME OF SETTING.

A common test, and one of much practical importance, is the time of setting together with the auxiliary test, rise in temperature of paste during setting. This latter test is, however, both valueless and dangerous, except in the hands

of an expert, under whose manipulation it will indicate imperfect composition and freshness in cements.

Vicat devised the original apparatus for determining the rate of hardening of lime mortars. In the tests as recommended by Vicat, the weighted needle was allowed to fall into the material under test. The tests as now used, the needle is applied carefully to the surface and allowed to sink into mass under a given weight. Gilmore's wires are commonly used, but as they are likely to be applied in an irregular manner at an acute angle, giving rise to great discrepancies in the results of the test, they are not as desirable. These wires (Plate VI, *Fig. 2*) are the one-quarter on a needle having $\frac{1}{12}$ of an inch area for the initial test, and 1 pound on a needle having $\frac{1}{24}$ of an inch area for hard set. An excellent modification is one in which an upper guide keeps the needle in a perpendicular position.

In Germany, the set is determined by noting the time which elapses before the cement will resist the firm pressure of the thumb-nail. Both the Gilmore wire test and thumb-nail test give misleading results, since they are made on the surface of the mass only. For this reason I prefer the Vicat needle apparatus, because the needle penetrates into the mass; and while it is true the final set is just as hard to determine, yet the "initial set" and the most important test is very readily determined. It is very difficult to decide the exact time the needle ceases to make an impression. In slow-setting cements different persons will vary greatly as to the determination of this point. In the Vicat apparatus the needle is applied perpendicularly. M. Bonnami modified the Vicat test by defining the initial set as the time elapsing before the needle under a load of 50 grams, sank into the mass half-way, and hard set as the time when it sank half-way under a load of 3,000 grams. I am of the opinion that the hard set should be defined as the time which elapses before the penetration of the needle ceased to pass a point just below the surface. The determination of the time of setting is only approximate, the results being materially effected by the temperature of the mixing water and of the air during the test, the humidity of the atmos-

phere, the percentage of water used and the amount of molding the paste receives.

As cement usually loses strength by retempering, it is necessary to have a general idea of how long it takes cement to set and thus provide against retempering of the mortar on the work. Set tests are made on neat cement pastes only, as in sand mortars the grains of sand impede the free penetration of the needle.

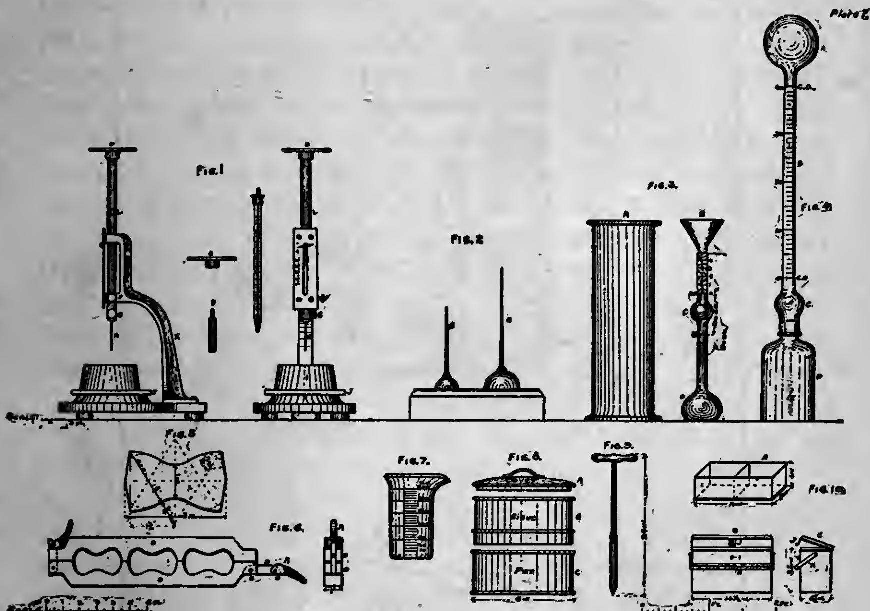


PLATE VI—Fig. 1, Vicat needle; fig. 2, Gilmore wires; fig. 3, Le Chatelier specific gravity apparatus; fig. 4, Candlot specific gravity apparatus; fig. 5, Am. Soc. C. E. briquette; fig. 6, gang mold; fig. 7, measuring glass; fig. 8, sieve; fig. 9, sampling iron; fig. 10, collection can.

The following is a description of the Vicat needle apparatus:

The Vicat needle, illustrated in *Fig. 1*, Plate VI, consists of a frame K, bearing the movable rod L, having the cap D at one end and the needle H having a circular cross-section of 1 square millimeter at the other. The screw F holds the needle in any desired position. The rod carries an indicator, which moves over a scale (graduated to centimeters)

borne by the frame *K*. The rod with the needle and cap weighs 300 grams; the paste is held by a conical hard rubber ring *I*, 7 centimeters in diameter at base, 4 centimeters high, resting on the glass plate *J*, 15 centimeters square.

For neat pastes the setting is said to have commenced when the polished steel needle, weighing 300 grams, does not completely traverse the mass of normal consistency confined

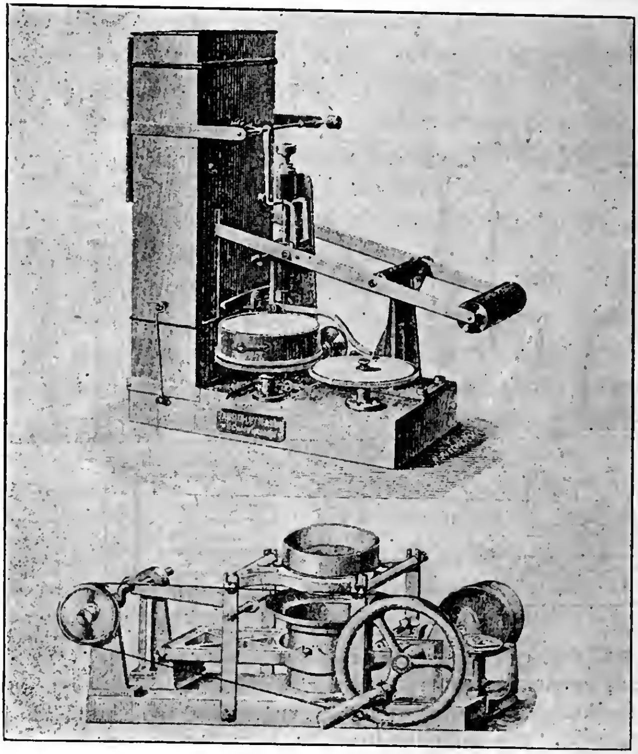


PLATE VII—Fig. 1, Amsler-Laffon "time of setting" machine; Fig. 2, Petmajer sieving apparatus.

in the rubber ring, and the setting is said to be terminated when the same needle gently applied to the upper surface of the mass does not sink visibly into it.

A thermometer *C* graduated to $\frac{1}{5}$° C. is stuck into the mass and the increase of temperature of mass during setting can be thus observed. The paste is kept in the moist closet

during the operation, being removed only to make trial tests of the setting.

Care should be taken to keep the sides of the needle clean, as the collection of cement on the needle retards the penetration of the needle, while cement on the point of the needle reduces the area of needle and tends to increase the penetration.

The test specimens should be kept in moist air during the test. This is best accomplished by placing the specimens on a rack over water contained in a pan covered with a damp cloth, kept away from the specimen by a wire screen The specimens can also be kept in a moist closet.

It is impossible to catch the exact time of either the initial or hard set unless one continuously observes the set ting, usually the trial test is made just before or just after the set. Several appliances have been devised for recording the setting automatically and autographically; probably the best is that made by Amsler and Laffon, of Switzerland. (Plate VII, *Fig. 1.*) There is also an automatic appliance in the cement laboratory of Cornell University.*

[*To be continued.*]

THE ELECTRO-METALLURGY OF ZINC.

Commenting on the highly interesting and suggestive presidential address of Mr. J. W. Swan, F.R.S., lately given to the Society of Chemical Industry, and which was devoted to an exhaustive review of the electro-chemical industry, the *Electro-Chemist* has the following to say as to his references to zinc:

"Foremost in importance among the metallurgical problems mentioned by Mr. Swan still awaiting satisfactory solution stands the economical extraction of zinc from its ores. To realize the appalling wastefulness of the present methods of zinc smelting it is only necessary to bear in mind that in the very best practice from ¾ to 1 ton of coal are consumed in producing from 1½ to 2 tons of spelter from a 50 per cent. ore. Now, although, of course, the same amount of energy has to be expended in order to isolate 1 ton of zinc, whether it be chemically reduced or electrolytically deposited, yet the conditions under which the energy is extracted from coal and then utilized are so much more favorable in a good modern boiler, steam-engine and dynamo plant than in a zinc-smelting furnace, that the advantages would be all on the side of the electrolytic process, both as regards cost of production and purity of product, were only that process forthcoming. But unfortunately the econ-

* Spalding, "Hydraulic Cement." P. III.

omy of electrolytic zinc extraction processes is not so great as would at first appear. The reason of this is to be found in the fact that in the leach, previous to electrolyis, any silica which may be present in the ore is rendered gelatinous by the action of the acid, and it then holds a considerable quantity of zinc solution; consequently filter-presses must be used, and even then the extraction is only partial. The formation of this gelatinous silica may be overcome when treating ores which do not originally contain zinc silicate by roasting at a lower temperature, but in this case the zinc sulphide is only partially decomposed, and consequently is not acted on by the leaching medium. As often as the problem has baffled the skill of inventors, so sanguine are electro-chemists of its ultimate successful solution, which will probably be on the lines of an electrolytic leach, to which the above remarks do not apply; and, indeed, Brunner, Mond & Co. exhibit at Glasgow specimens of zinc of 99·96 per cent. purity, which Mr. Swan reports as having been made electrolytically on the lines suggested in the well-known Hoepfner patents."

FERRO-SILICON.

In his Presidential address before the Society of Chemical Industry, Mr. J. W. Swan refers to ferro-silicon as one of the newer class of alloys now being produced on a commercial scale by the electric furnace. At present the demand is small, and the production exceeds the requirements, but it is hoped that in time there may be a large demand for this alloy in connection with the manufacture of iron and steel. It has been proved that, where there is no excess of carbon, silicon improves some of the physical properties of steel, and that its thermal energy is of value in steel casting. Ferro-silicon is at present being manufactured at Meran, in the Austrian Tyrol, and at other carbide works in France.

Scrap iron, quartz, and coke are used as raw materials of the manufacture The daily yield of each furnace is 1,200 kilos. The product contains 77·5 per cent. Fe and 21·5 per cent. Si, and costs at Meran £8 per ton. The yield in the electric furnace is one ton per 5,000 k.w. hours.

X-RAY SLOT MACHINES.

The X-ray and the slot machine are modern utilities that have finally combined their energies to make a sidewalk show for the curious possessor of the nickel indispensable to operation. The apparatus includes a vertically mounted fluoroscope, which may be used when the tube is made active by dropping a nickel in the slot. The passer-by who desires to see the bones of his hand or wrist makes his contribution and places his hand in the proper position; the machine does the rest. With the exception of the fluoroscope, the necessary parts are enclosed, with suitable openings. The machine seems to be self-contained and is of a convenient height for use by a man of average stature. One of these curious machines has been placed in a Chicago restaurant, and it excites much attention from its novelty. The apparatus is built to afford pastime, principally, but it is also calculated to give the man-in-the-street a glimpse of natural phenomena that he might not otherwise obtain.—*Western Electrician.*

Section of Photography and Microscopy.

Stated Meeting held Thursday, November 7, 1901.

ON THE USE OF SENSITIVE PAPER IN X-RAY WORK

BY M. I. WILBERT.

The use of so-called "bromide papers" in X-ray work is, of course, not new or original. Roentgen himself, in his early publications on the subject of the X-rays, intimated that he had used sensitive photographic paper in the course of his investigations and experiments, and many if not all X-ray operators have from time to time made use of this variety of photographic material in their experimental work. The objections that most experimentors have had to contend with in the ordinary commercial brands of paper is the fact that the surface of even the so-called smooth paper is a decided matt. This matt surface gives the resulting picture the appearance of being buried in the texture or pores of the paper, with a consequent loss of much of the necessary detail. The finish or surface of this matt-surface paper is of such a nature that squeegeeing on glass or ferrotype plate does not materially improve the surface or appearance of the picture.

Of late years, several manufacturers have put upon the market a glossy variety of developing-paper as a substitute for, or to compete with, the well-known varieties of printing-out papers. This glossy variety of developing-paper has the advantage of keeping the image on the surface, and for this reason is well adapted for the reproduction of more detail in the picture.

It should be remembered that the developing-papers now on the market vary greatly in speed, or the amount of exposure that is necessary to produce the latent image, and it is obvious that the slow varieties now so extensively used, especially by amateurs, and in which the sensitive silver salt is composed largely, if not entirely of a chloride, are not

at all suited for X-ray work. We must confine ourselves therefore to the older and comparatively rapid bromide papers.

The particular paper that I myself have been most successful with is a comparatively new German brand of bromide paper now being introduced into this country. It is made by the "Neue Photographische Gesellschaft" in Berlin, Germany, and is marketed in different grades of smooth, glossy and rough; it is coated on what appears to be a very excellent quality of paper stock.

The glossy variety is one that is best adapted for X-ray work, on account of the smooth finish and fine texture of its surface. How well it is adapted to this particular purpose may be determined by an inspection of the samples shown here.

The question naturally arises, What possible advantages are to be derived from the use of sensitive paper instead of glass plates? The possible advantages are many, and it is my purpose now to call attention to some of the more evident points of vantage as they have occurred to us while experimenting with the various brands of bromide paper available at the present time.

First, the matter of price: in this the use of paper would result in a saving of from forty to sixty per cent. of the cost of dry plates. Other things being equal, this one feature alone would be of sufficient importance to insure the very wide use of a sensitive paper that could be relied on to give satisfactory results under all conditions and at all times.

Another advantage is the saving in possible breakage. Every X-ray operator has had experience in this line. The breaking of a glass plate usually occurs towards the end of an exposure, and always in a case that has necessitated a considerable amount of care in the preparing for and patience in making the exposure. The ominous click that accompanies the accident not only means the loss of a rather expensive plate, but also a waste of the time and energy that has been expended in preparing for and in making the exposure. Nothing of this kind is at all likely to

occur with paper, so that the exercise of ordinary precaution would insure us against any possible danger of wasted exposures.

The facility with which the resulting pictures may be stored will, of course, appeal to all, as the difference in bulk and weight is self-evident. One feature of considerable importance in this connection is the fact that the name of the patient and all the necessary data relating to the case or the making of the exposure may be written on the back of the exposed sheet before development, in this way obviating any possible chance of making a mistake by confusing two or more of the resulting pictures.

Many physicians who are not familiar with, nor in the habit of looking at photographic negatives, cannot see detail in a transparent plate, and, consequently, prefer to have a print. This opens up another possible field for sensitive paper. Not only would the use of this paper obviate the necessity of making positive prints, but we may, if we choose, utilize the paper in combination with glass plates for the same purpose. By exposing a piece of paper and a glass plate at the same time, and developing them in the same solutions, we not only make the paper print and the glass negative at the same time, but we also, in addition to this, have a more or less valuable means of control; for by comparing our results a possible flaw in the plate could not possibly be mistaken for a pathological condition of the part of the patient radiographed.

If for any reason we desire to have two or more prints of the same subject, we can readily obtain them by exposing the required number of sheets of paper at the same time. The paper itself offers little or no resistance to the rays, so that we can expose a dozen sheets as readily as we could one.

Probably the greatest advantage is the rapidity with which we can obtain the desired information. Those of you who have had any experience in this line well know how anxious the doctor usually is to see the result of the exposure; you also know that a plate in the process of development is not always the most reliable source of infor-

mation, so that, under ordinary circumstances, we are obliged to wait until the plate is sufficiently fixed to be transparent. This extra wait for the fixing bath can be avoided by using paper, as, after proper development and a thorough rinsing in water, the resulting picture may be examined in broad daylight without any appreciable damage by fog or other change of the residual silver salts. The necessary fixing in hypo may be done later.

These are but a few of the possible points of superiority that have presented themselves to us while experimenting, or in the regular routine use of the X-rays.

There are, of course, drawbacks and defects in paper at the present time. One of them is the comparative slowness of the emulsions used on ordinary bromide papers. This, to some extent, has been overcome by this same German company, in what they call their negative paper, the emulsion on which is much richer, and, consequently, more rapid than that used on their regular grades of paper. This negative paper is very thin, and is intended to replace celluloid films, and also the various kinds of stripping films that are at present being reintroduced and used quite extensively, especially in Germany. This thinness or transparency of the paper would also tend to do away with another rather serious objection to heavy bromide paper—the tendency for an image, especially of the heavier portions of the body, to veil over or fog; a perfectly transparent paper would give us all the possible advantages of a glass plate in this respect. There remains but one more serious question, and that is the keeping-quality of paper coated with a very sensitive emulsion of silver salts; and, while this may possibly be a serious, or rather a difficult problem, there appears to be no positive reason why manufacturers cannot obtain a paper that will not affect the sensitive salts in the emulsion.

In addition to its use as a substitute for glass plates in taking the impression direct, glossy bromide paper can, of course, be used to advantage for reproduction, or the making positive prints from X-ray negatives. For this purpose the German brand of paper also has some points of supe-

riority; for, in addition to its being a very rapid paper, so far as the time necessary for exposure is concerned, it has the added advantage of being a slow or rather steady developer, so that we have considerable latitude in this step of the process, and can modify the resulting picture to a considerable extent by either accelerating or retarding the same in the course of its development.

Those of you who are in touch with or consult German photographic or X-ray journals will probably recall the really beautiful reproductions on bromide paper that these journals occasionally contain. This so-called method of "light printing," while it appears to have originated in this country, does not seem to have been developed or followed to any considerable extent. In Germany, on the other hand, it has evidently been developed into a distinct branch of the printer's or, rather, the photographer's art. The printing and developing of these pictures is done automatically, by means of specially constructed machines, and it would appear that there was a possibility of developing this same method of photographic printing in this country so as to make it available for illustrating books and periodicals in cases where the presentation of detail is considered of sufficient importance to assume a possible slight increase in cost.

ELECTROCHEMICAL WORKS AT NIAGARA.

The *Electro-Chemist* gives the following interesting data :

The present total output of electricity at Niagara is about 50,000 H.P.; of this no less than 23,200 H.P. is consumed in electrolytic and electric smelting operations. This power is distributed as follows :

	H.P.
Electrical Lead Reduction Company	500
Acheson International Graphite Company	1,000
Pittsburgh Reduction Company	5,000
Carborundum Company	2,000
Matthieson Alkali Works	2,400
Niagara Electrochemical Company	500
Ampère Electrochemical Company	300
Union Carbide Company	10,000
Oldbury Electrochemical Company	1,000
Roberts Chemical Company	500
Total	23,200

Cassier's Magazine for May gives some interesting statistics in connection with these works.

The Electrical Lead Reduction Company reduce lead from its sulphide in the form of sponge, principally for the manufacture of litharge. The original alternating current at 2,200 volts is used for induction motors, which in turn drive direct-current dynamos which generate current at 100 volts. (See *Electro-Chemist and Metallurgist*, i. p. 32.)

The Acheson International Graphite Company convert anthracite into graphite in the electric furnace. The current is used at 80 volts pressure. (See *Electro-Chemist and Metallurgist*, i. p. 89.)

The Pittsburgh Reduction Company, it is needless to say, extract aluminium from baeuxite by the Hall process. (See *Electro-Chemist and Metallurgist*, i. pp. 2, 10.) The two-phase alternating current, which enters the works at 2,200 volts, is converted first to 130 volts and then by rotary converters, each of 600 kilowatt capacity, to direct current at 160 volts.

The Carborundum Company produce silicon carbide in 110-volt alternating-current electric furnaces.

The Matthieson Alkali Works transfer the 2,200 volts two-phase current into direct current at 230 volts. They produce chloride of lime and caustic soda by the Castner process.

The Niagara Electrochemical Company convert their current into direct at 165 volts for the production of sodium and sodium peroxide from caustic soda.

The Union Carbide Company work their electric furnaces (200 H.P. each) at 110 volts and 25 alternations. According to *Cassier*, this company probably uses more electric power than any other one factory in the world.

The Roberts Chemical Company use direct current at low voltage for the production of caustic potash, etc.

GLASS COLORING BY PENETRATION.

M. Léon Lémal proposes to color glass, not throughout the mass nor in enamel fashion, but by what he calls penetration. A little silver salt is put on the surface of the glass, which is then heated to 500° or 550° C. The excess of salt having been removed, the surface appears yellow, the color penetrating to a depth of 0·17 millimeters when the baking has lasted for about five minutes. After an hour, a layer of double that thickness would be colored; after eighteen hours the color would have penetrated through a glass plate 1·6 millimetres in thickness. In reflected light this yellow displays a beautiful greenish or blueish fluorescence. The intensity of the coloration depends, of course, upon the quantity of salt applied. But very minute quantities suffice. To transfer a lace pattern on glass, it is only necessary to dip the lace in a 0·001 solution of silver nitrate and then into potassium sulphide. According to *La Nature*, colored monograms can easily be obtained in this way, and what is still more interesting, ordinary collodion negatives can be printed on glass in various colors. Silver and copper give a red; gold and iron salts have also been used. When the baking is continued for a long period, the coloring matter is renewed from time to time, say every six hours. The observation has a scientific interest as well. The rate of penetration would probably depend upon the nature of the glass, and upon the atomic volume of the metal. W.

SHIMER'S COMBUSTION APPARATUS.

[*Being the report of the Franklin Institute, through its Committee on Science and the Arts, on the invention of P. W. Shimer, Easton, Pa. Sub-Committee: Dr. H. F. Keller, Chairman; Dr. Jos. W. Richards, G. H. Clamer.*]

HALL OF THE FRANKLIN INSTITUTE,
[No. 2179.] PHILADELPHIA, June 5, 1901.

The Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts, acting through its Committee on Science and the Arts, investigating the merits of Shimer's Combustion Apparatus, reports as follows:

Among the more difficult and time-consuming routine work of analytical laboratories, particularly in iron and steel works, is the determination of carbon by the combustion method.

This method consists in strongly heating in a current of pure oxygen a weighed quantity of substance containing the carbon, or the latter after it has been separated from the substance, and collecting the resulting carbon dioxide in caustic alkali. The percentage of carbon is then calculated from the increase in weight of the alkali.

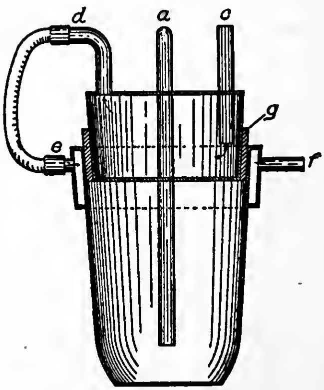
The apparatus heretofore generally employed for this purpose included a number of expensive and bulky parts, such as a combustion furnace, tubes of platinum, porcelain, or hard glass, and a supply of oxygen gas. The use of this apparatus is extremely wasteful, inasmuch as the quantity of fuel consumed in the furnace, and the heat generated in it, are out of all proportion to the small amount of carbon to be oxidized, and, in spite of this great waste, the complete combustion of graphite presents considerable difficulties where the pressure of the gas supply is small.

In the invention before your committee, the cumbersome furnace is replaced by a blast lamp and Bunsen burner; a crucible of special construction takes the place of the combustion tube, and air is substituted for the oxygen.

The essential and novel part of the apparatus consists in a platinum crucible, the upper part of which is water-jacketed, and a water-cooled stopper made of copper, provided with inlet and outlet tubes for the air.

Internally the crucible has the same shape and dimensions as the crucibles commonly used for fusions; the cooling chamber is on the outside, it is $\frac{1}{2}$ of an inch wide and $\frac{1}{8}$ of an inch deep, and has short inlet and outlet tubes, *e* and *f*, placed horizontally and on opposite sides. The whole is made of platinum and in a single piece.

The hollow stopper is made of sheet copper, and perforated to give passage to the copper tube, *a*, which serves as inlet for the air in the crucible, and provided also with



inlet and outlet tubes, *c* and *d*, for the cooling water. All the joints in this stopper are carefully brazed (see illustration). The flare of the sides of the stopper conforms closely to that of the crucible walls, but the stopper is made somewhat smaller than the crucible opening, in order to allow space for a small rubber band which serves to make an air-tight joint between stopper and crucible. The cooling chambers of the crucible and stopper are connected by a rubber tube, so that the same water may pass through both.

The rubber band is thus, on both sides, in contact with water-cooled metallic surfaces, and there is no risk of its

burning or softening when the lower part of the crucible comes to a bright red-heat in the course of a combustion.

The trains for purifying the air and absorbing the products of combustion are identical with those formerly used.

The advantages gained by Shimer's construction of the combustion chamber are as follows :

(1) The replacement of a bulky and complicated apparatus by one of compact and simple construction.

(2) A considerable saving in the cost of the apparatus and repairs.

(3) A very great economy in the gas used for heating.

(4) The possibility of effecting a rapid and complete combustion of graphite and carbon in difficultly soluble alloys in laboratories where gas is supplied at a low pressure.

(5) The use of the crucible for the determination of combined water and carbonic acid in minerals, ores, cements, etc.

After having carefully examined and tested the apparatus, your sub-committee is satisfied that its construction embodies novel and valuable features, and that it must be regarded as a greatly improved form of one of the most important laboratory appliances. The judgment of your sub committee is corroborated by the facts that the invention, although patented less than a year ago, has already found its way into most of the laboratories of the iron and steel works of this country, and that a large number of unsolicited testimonials from the heads of those laboratories agree that it effects economy in time, labor and expense.

In view of the ingenuity displayed in the construction of this device, and its great practical value, your sub-committee respectfully recommends the award of the John Scott Legacy Medal and Premium to the inventor by the Franklin Institute, through its Committee on Science and the Arts.

Adopted at the stated meeting of the Committee on Science and the Arts, held Wednesday, October 2, 1901.

Attest : WM. H. WAHL, *Secretary.*

BOOK NOTICES.

Theoretical Elements of Electrical Engineering. By Charles Proteus Steinmetz. 8vo, pp. vii + 327. New York: Electrical World and Engineer, Inc., N. D. (Price, $2.50.)

This work is divided into two parts. Part I treats, under eighteen heads, the fundamentals of direct and alternating currents, with one or more examples under each head elucidating the theory.

Part II comprises a series of monographs descriptive of the more important electrical apparatus, alternating as well as direct current. These are treated under four divisions: (*a*) Synchronous Machines; (*b*) Commutating Machines; (*c*) Synchronous Converters; (*d*) Induction Machines. W.

Electrical Designs, comprising instructions for constructing small motors, testing instruments and other apparatus, with working drawings for each design. Reprinted from the *American Electrician.* 8vo, pp. viii + 262. New York: American Electrician Company, 1901. (Price, $2.00.)

This work is a reprint of a series of articles giving details of the construction of a great variety of electrical apparatus and machinery, most of which have been actually built and operated.

They embrace specifications and working drawings of a number of motors and generators of various types, transformers, rheostats, meters, galvanometers, testing sets, photometers, lamps, induction coils, batteries, etc. The writers of these articles are all well known. W.

Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, November 20, 1901.*]

HALL OF THE INSTITUTE,
PHILADELPHIA, November 20, 1901.

President JOHN BIRKINBINE in the chair.

Present, 180 members and visitors.

Additions to membership since last month, 30.

The President in a brief address referred to the recent occurrence, in this city and vicinity, of an abnormal number of disasters destructive of life and property (see appendix), and suggested that the subject be referred to a special committee to consider whether some action could not properly be taken by the Institute that would reduce the hazard to life and property traceable to our industrial growth and methods of transportation.

Dr. Samuel W. Stratton, director of the newly established National Bureau of Standards, read an interesting paper on the organization and work of the bureau. (Paper and discussion thereon will appear in the JOURNAL.)

Mr. Martin I. Wilbert described his experience with the use of Sensitive paper in X-ray work, and exhibited numerous specimens of his work. (Referred for publication.)

Mr. F. E. Ives made a communication on "The Half-tone Trichromatic Process," and illustrated the subject by means of his specially devised camera and with specimen prints. (Referred for publication.)

Under new business, Prof. Lewis M. Haupt called attention to the bill of Senator Frye presently to be considered by the Congress of the United States, to create a new Department of Commerce and Industries. He urged the propriety of an endorsement of this measure in general, but proposed that the Institute should suggest that the bill be amended so as to permit of river, harbor and other improvements being made by the citizens of localities affected thereby, at their own cost, when no public money was available for the purpose.

Professor Haupt offered the following preamble and resolutions in support of his argument, viz.:—

RESOLUTIONS TO PROMOTE COMMERCE.

Whereas, Greater and cheaper transportation facilities are essential to the development of our domestic and foreign commerce;

Whereas, The limited biennial appropriations are wholly inadequate to meet the requirements of the country, being only about eight per cent. of the approved projects;

Whereas, The former policy of authorizing the improvement of our waterways by private capital resulted in a rapid development without cost or risk to the general Government;

Whereas, Early and economical results may be secured by a partial return to this method in localities where no provision has been made for immediate improvement;

Whereas, It is proposed to create a Department of Commerce to exercise general jurisdiction over transportation on land and water; therefore, be it

RESOLVED, That said Department of Commerce should be empowered to authorize the improvement, by individuals or by corporations, of such rivers, harbors, canals or other waterways as are not provided for under the River and Harbor or the Sundry Civil Bills, and upon plans and regulations to be approved by the said Department; *Provided*, that no part of the funds for such works shall be drawn from the public treasury of the United States.

RESOLVED, That the establishment of a Department of Commerce and Industries is approved and its early inauguration recommended.

On motion of Mr. Thos. P. Conard, numerously seconded, the subject, with preamble and resolutions, was referred to a special committee of five, to be named by the President, with instructions to report at the next stated meeting of the Institute.

On Dr. Geo. F. Stradling's motion it was resolved that a special committee be appointed by the President, to consist of one member from each of the Sections and three from the membership-at-large, to consider the advisability and feasibility of the adoption of the metric system in the United States.

Mr. A. E. Outerbridge, Jr., referring to the introductory remarks of the

President bearing on the increasing hazards to life and property, associated with the expansion of our manufactures and transportation methods, moved that a special committee be appointed, in conformity with the President's suggestion, to consider and report upon the subject at a future meeting. Carried.

After some discussion of Dr. Stratton's paper, the meeting adjourned.

WM. H. WAHL,
Secretary.

APPENDIX.

REMARKS OF MR. JOHN BIRKINBINE MADE TO THE MEMBERS OF THE FRANKLIN INSTITUTE.

The Franklin Institute, with a membership distributed over the United States, and having many foreign members, does not ordinarily take cognizance of local matters, although the Institute was originally a local organization and its membership has broadened because the value of its work was recognized. However, a large propotion of the active members are resident in or near the city of Philadelphia. Even if this were not the case, consideration of some affairs affecting this locality can properly come before it, particularly as these have a widespread application and command general interest.

Within a few months a number of abnormally serious disasters, some resulting in great sacrifice of life, have been chronicled in this immediate vicinity—disasters of such moment as to invite attention much beyond the immediate locality of Philadelphia. An explosion destroying several houses on Locust street; the wreck of the steamboat "City of Trenton" by a boiler explosion; the destruction of a business house on Market street in the heart of the city where, in mid-day, the lives of more than a score of persons were sacrificed, are very late instances. Others could be mentioned, such as explosions due to chemicals and gasolene in various parts of the city, and the falling of a business building in the centre of the city owing to work about its foundations—surely, sufficient to suggest an inquiry as to why such disasters should occur in or about a great city which is renowned for the technical knowledge and practical experience of many of its citizens. Here are colleges; institutions like the Franklin Institute; preparatory and trade schools; many and varied industries; armies of skilled artisans and mechanics; numerous technical specialists; also Government, State and Municipal officers clothed with authority under statutes to inspect and, if necessary, condemn doubtful structures or apparatus, and yet, within a very brief interval a series of terrible disasters, replete with sickening details, have resulted in horrible sacrifices of life and great loss of property.

Such occurrences have not been restricted to this locality, but other portions of the conntry have contributed their quota, and most of the large cities and some of the smaller ones could add to the record of accidents (often misnamed) in mine, shop or factory, which would make a story of disasters appalling in its array of loss and danger.

The great majority of these can be credited to one of four causes:

First. The laws are insufficient to secure the required protection to life and property.

Second. Such laws as exist are not enforced, or enforced with such laxity as to be equally dangerous.

Third. Lamentable ignorance or gross carelessness on the part of those who design, construct or operate plants or industries.

Fourth. Public indifference, due to familiarity with existing dangers, until local disasters cause spasmodic awakenings, followed too quickly by normal conditions.

Your attention was invited to one phase of danger by the address of Mr. McDevitt two months ago, and the Engineering Section has under discussion boiler design, having given particular attention to the wreck of the "City of Trenton," and an expert jury is, under the coroner's direction, now discussing the subject of fireproof buildings and fire escapes. But we should not stop at this. The Institute many years ago prepared a report on boiler explosions which is to-day considered an authoritative expression. The Engineering Section may supplement this by the result of its inquiry.

It would seem that the time is ripe for a general discussion upon reducing hazards to life and property traceable to our industrial development and transportation methods.

It is not presumed that such discussion is to fix responsibility for disasters, for this is a grave matter which it is not the function of the Institute to locate; but we may be able to trace the causes with the expectation of suggesting remedial measures by a full and fair discussion of the deficiencies in existing laws, and possibly indicate failures to enforce protective measures which have been provided. We certainly could arouse public sentiment and probably be the means of instructing some upon details which have been imperfectly recognized. Such an investigation is in line with the work of the Franklin Institute and in keeping with its functions. It will probably result in a committee making a report to the Institute which, if adopted, will carry the weight which has always been accepted as representing the honored name of our organization. It is recommended that a committee, upon which there shall be a representative of the Committee on Meetings and of each of the Sections to which details of the investigation would fall, in addition to members selected from the Institute-at-large, be formed to consider the hazards to human life and property traceable to our industrial development and transportation methods.

SECTIONS.

(*Abstracts of Proceedings.*)

PHYSICAL SECTION.—*Stated Meeting*, September 25th, 8 P.M. Dr. Geo. F. Stradling in the chair.

Mr. Wm. McClellan, of the University of Pennsylvania, presented a communication entitled, "A Review of Recent Progress in Heat." Discussed by Messrs. Stradling, Richards, Goldschmidt, and Pawling.

JESSE PAWLING, JR.,
Secretary.

CHEMICAL SECTION.—Proceedings of the *Stated Meeting*, held Thursday, October 24th, 8 P.M. Dr. W. J. Williams in the chair. Present, 18 members and visitors. The evening was devoted to the subject of "Explosions at Fires, with Suggestions as to Their Orgin," by Wm. McDevitt, Inspector to the Philadelphia Board of Fire Underwriters.

The speaker gave a number of experimental demonstrations of the explosibility of the chlorates, nitrates, and analogous mineral compounds, and of various organic products.

Discussed by Messrs. H. W. Jayne, H. F. Keller, C. A. Hexamer and others. In connection with the subject, Dr. Jayne mentioned the explosion of an empty glycerin drum by heatng.

W. E. RIDENOUR,
Secretary.

SECTION OF PHOTOGRAPHY AND MICROSCOPY.—Proceedings of the *Stated Meeting*, held Thursday, November 7, 1901, at 8 P.M. Dr. Chas. F. Himes in the chair. Present, 21 members and visitors.

The Special Committee on Photographic Record Work reported a revision of its classification of subjects proposed by Mr. J. W. Ridpath. The revised classification was approved.

The question of the size of plate to be adopted as standard was considered. Mr. J. E. Ives called attention to the fact that the 5 x 7-inch plate was the largest in general use by amateurs, and thought it would be advisable that the 6½ x 8½-inch plate specified in the report be changed accordingly. On Dr. Leffmann's motion, numerously seconded, this change was unanimously approved.

The committee's report, with the above amendment, was then adopted. (The report, as adopted, is hereto appended).

Specimens of albums made to embody the committee's views, were shown by Mr. Ridpath, and were freely criticized by the members.

The chairman presented for the album several prints of historical scientific apparatus, to wit: Dr. Priestley's original burning glass, with which he had made the discovery of oxygen; Priestly's air-gun, and other interesting subjects. He called attention to the desirability of having the descriptive matter appended to such records as full, though concise, as possible.

On Dr. Leffmann's motion, the Special Committee was instructed to proceed with the preparation of a record album, which should embody the suggestions brought out in the discussion of the subject.

Mr. Martin J. Wilbert followed with a paper on "The Use of Sensitive Paper in X-ray Work," which was illustrated with the aid of a large number of prints made in connection with the work of the German Hospital.

Dr. Henry Leffmann exhibited and described a series of lantern slides relating to modern methods of paper manufacture.

The same speaker called attention to the fact that the next meeting of the Section would be devoted to the subject of "Overexposure and Reversal in Photography," with especial reference to the investigations of Professor Nipher, of St. Louis.

By invitation, Mr. Wanner gave an account of some experiments that he had made in this direction.

Mr. Ives exhibited and described for Mr. Samuel Sartain a number of celluloid transparencies.

WM. H. WAHL,
Secretary pro tem.

APPENDIX.

[*Report of the Special Committee on Photographic Record Work.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, October 1, 1901,

To the Section of Photography and Microscopy:

The Comittee on Record Work, appointed in accordance with the resolution adopted at the stated meeting of the Section in May last, respectfully reports that it has held several meetings, and decided to recommend the following plans:

While photographs of any convenient size will be accepted if satisfactory, it is recommended that the 5 x 7-inch plate be chosen whenever possible.

As it is expected that albums will be provided by the Institute, prints should be sent in unmounted and properly trimmed. Except in special cases duplicates are not to be sent.

It is proposed that a supervising committee, chosen in some way that will secure the full representation of the Section, shall have charge of the acceptance of pictures and their arrangement in the albums or elsewhere.

Pictures become the property of the Institute, unless specific arrangements otherwise are made.

The committee offers the following classification of subjects, suggesting that the arrangement iu the albums or elsewhere shall conform to the system.

CLASSIFICATION.

(1) Machines, implements and scientific apparatus, especially those passing out of use; including manipulations in manufactures and trades.

(2) Transportation by land and water, ancient and modern.

(3) Buildings, bridges, and other useful structures, illustrating methods of erection.

(4) Buildings of historic interest, particularly scientific institutions, to include important ancient landmarks liable to be torn down.

(5) Portraits of distinguished men who have made important contributions to the sciences and mechanic arts.

(6) Documents of historic or public interest, including those of a scientific character.

(7) Catastrophies and incidents of public interest.

The committee has considered the question of albums, and submits various samples for the examination of members.

HENRY LEFFMANN,
U. C. WANNER,
J. W. RIDPATH,
Committee.

MINING AND METALLURICAL SECTION.—Proceedings of the *Stated Meeting* held Wednesday, November 13th, Prof. F. L. Garrison in the chair. Present, 32 members and visitors.

After the transaction of the usual formal business, Dr. J. A. Matthews, of Columbia University, New York, read a paper on "The Constitution of Metals and Binary Alloys." The communication was profusely illustrated with stereopticon views, and was discussed by Messrs. Paul Kreuzpointner, Robert Job, W. R. Webster, A. E. Outerbridge, Jr., James Christie, and the author.

Paper and discussion are reserved for publication in full.

G. H. CLAMER,
Secretary.

MECHANICAL AND ENGINEERING SECTION.—*Stated Meeting* held Thursday, November 14th, 8 P.M. Mr. James Christie in the chair. Present, 45 members and visitors.

The subject for discussion was "Steam Boiler Inspection, with Especial reference to Design, Construction and Service."

The discussion was opened by Mr. Geo. B. Hartley, and was participated in by Messrs. John M. Hartman, R. D. Kinney, Jos. C. Steinmetz, James Christie, and others.

The discussion will be printed as a supplement to the subject of the discussion held at the stated meeting October 10th.

DANIEL EPPELSHEIMER, JR.,
Secretary.

ELECTRICAL SECTION.—Stated meeting. Thursday, November 21st. Mr. Thomas Spencer in the chair. Present, 52 members and visitors.

Dr. A. E. Kennelly, in his remarks on the Electrical Arts at the Pan-American Exposition, took up the subject of high-tension switches, and gave an historical sketch of the development of the switch from its earliest form, in which a simple wire was laid across two terminals, to the special devices in use to-day which control currents equivalent to capacities of 5000 horse-power. He spoke successively of the bell switch, the earliest types of knife switches and automatic circuit breakers, and the oil switches, and special high potential switches which are now being used, all of which showed the great amount of ingenuity which had been displayed in their design and manufacture.

Regarding the Edison storage cell, he stated that no tests had lately been made as to its efficiency, but exhibited several plates which are used in this type of cell.

Mr. C. J. Reed spoke on polarization in batteries, and called attention to the numerous different definitions which had been given to this term; each definition was correct if taken from the point of view of the definer; but none of them seemed to really take in the actual effects or results which took place in the batteries. Mr. Reed thought that the proper definition of polarization was a progressive electro-chemical exhaustion of the electro-chemical reagents.

Paper was discussed at some length and discussions proved of considerable interest.

RICHARD L. BINDER,
Secretary.